UE Research Journal
Vol. 26 (2024): pp. 67-102

Hybrid Home Automation of Common Electronic Devices using Fog Computing with Data Analytics: A Philippine Set-Up

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Abstract

The study developed a hybrid home automation system using fog computing that covers the design plan, specifications, and implementations of the convergence of IoT devices such as the IP-Based Closed-Circuit Television (CCTV), Access Control like Electronics Door Lock, Fire Detection and Alarm Systems (FDAS), and automatic lighting systems combined in one network infrastructure and managed by a central controller located in the fog layer at a hierarchical model. It focused on the design and development of hybrid home automation of common electronic devices with multiple systems and multiple brands in a single network infrastructure with data analytics specifically in Philippine settings. This study is considered as both descriptive and developmental which describes the system evaluation ISO using the Interoperability for IOT systems framework (ISO/IEC 21823-1:2019) based on Interoperability such as Transport, Syntactic, Behavioral, Policy, and Semantic Interoperability.

Keywords: Internet of Things (IoT), fog computing, Wi-Fi, Apps, Script, home automation

The fast adoption of Internet of Things (IoT) solutions in industries and home automation has created new obstacles and issues, such as device compatibility among vendors, device integration with existing network infrastructure, and security. These new challenges are usually faced by design engineers, system integrators, and contractors of home automations. As discussed by Cyril and Malekian (2015), the concept of home automation has been around since the late 1970s. But with the advancement of technology and services, people's expectations of what a home should do or how the services should be provided and accessed at home has changed a lot during the course of time, and so has the idea of home automation systems.

Home automation may refer to isolated programmable devices like smart thermostats and sprinkler systems, but it more accurately describes homes with nearly everything connected to a remotely controllable network, including smart outlets, smart light switches, appliances, and heating and cooling systems. Home automation enables the homeowners to control appliances and electronic devices. From a home security perspective, this comprises the alarm system and all connected doors, windows, locks, smoke detectors, security cameras, and other sensors. A "smart home" is a part of the IoT paradigm and aims to integrate home automation. Allowing objects and devices in a home to be connected to the Internet enables users to remotely monitor and control them (Lee, 2016).

Moreover, IoT devices from various vendors for home automation usually comes with their own applications (Apps), which populate the home automations' panel or Human Machine Interface (HMI) with different drivers and applications. In the Philippines, design engineers like Electronics Engineers (ECE) and Professional Electronics Engineers (PECE) usually refer to the Code of Technical Standards. The Institute of Electronics Engineers of the Philippines (IECEP) is the accredited professional organization (APO) of Professional Regulation Commission (PRC) that published and released the said code of standards. There are four codes, namely, Telecommunication System, Fire Detection and Alarm System (FDAS), Community

Antenna Television (CATV), and Distributed Antenna System (DAS) (Republic Act No. 9292, 2022).

The primary impetus behind the study is because there are no existing codes and standards yet even in other countries for IoT and home automation, especially multiple system, and multiple brands. These lead to the complexity on the part of design engineers, integrators, and contractors. Added here are the emerging standards in home automations and the rapid changes of technologies.

In many businesses and organizations in the Philippines, digital authentication is a huge deal. Examples include managing the access control system when entering and leaving a location, specifically, using digital authentication to lock and unlock doors as opposed to traditional keys.

This study addressed these challenges of integrating multiple system, multiple vendors, and the lack of standards in home automation by creating a home automation system that focuses on design plan, specifications, configurations, installation procedures, and testing procedures.

The study pointed out the gaps in energy efficiency and cost savings: since implementing a hybrid home automation system with data analytics in Philippine households covered expensive IoT devices and used cloud computing. Infrastructure Costs is the primary issue Cloud computing utilizes centralized data centers, which call for large infrastructure investments in the form of servers, storage systems, networking hardware, and cooling systems. One disparity is the data transfer fees, where the data exchanges between the cloud servers and the home automation equipment are a common part of cloud computing. Data transfer fees may be assessed by cloud service providers, particularly if the amount of data transferred exceeds predetermined thresholds. Fog computing eliminates the need for frequent data transfers and their related expenses by doing data processing and analytics locally.

The novelty in this study lies in the hybrid home automation system that combined the script development and implementation in integrating multiple system and multiple brands. The result could be used as a guide by the design engineers, system integrators, enthusiasts, and contractors for their home automation projects.

The hybrid home automation system is composed of numerous systems combined in one network infrastructure and managed by a central controller located in fog layer at hierarchical model. The home automation system is composed of IP-Based Closed-Circuit Television (CCTV), access control like electronics door lock, Fire Detection and Alarm System (FDAS), automatic lighting system and electrical power outlet. The controller used in this study is fog computing which offers ultra-low latency, real analytics, less bandwidth, and network load, added security, and offers reduced cost compared to the cloud-based system automations (Dastjerdi and Buyya, 2016).

The design catered to the different systems that are commonly found in home automation system, such as, IP-Based Closed-Circuit Television (CCTV), access control like electronics door lock, Fire Detection and Alarm System (FDAS), automatic lighting system and electrical power outlet. In terms of security, home automation systems are becoming more prevalent, and with the increasing number of smart devices, security is becoming a significant concern. Fog computing can be used to enhance security in home automation systems by providing a distributed computing architecture that allows for data processing to occur at the edge of the network, closer to the source of the data. Security system was deployed via data encryption in transit between devices in the home automation system. This helps to prevent unauthorized access to sensitive data by hackers or other malicious actors. The authentication and authorization mechanisms for every network device were made visible. Intrusion detection was set-up to alert the homeowner or security personnel when a security breach is detected.

The burglar alarm system and the sprinkler system in FDAS were not included in the study since the intended mock-up prototype system was for a single-story house. Network security was limited to the features of network devices to be used, hence, MAC address filtering, static IP addressing scheme, IP reservations, and URL filtering, were employed as basic security for the network.

Software engineers, engineers, integrators, and contractors in the Philippines for design development of home automation systems and homeowners for a more affordable robust automation system. Other developers for the continuous development of hybrid home automation systems given that these systems still have room for improvements and innovations. This might have inspired developers to delve into this field of study. Lastly, for future researchers for relevant concepts, facts and information found in this paper which can be a valuable support. Moreover, this study may stimulate ideas for other researchers thus, improving the capabilities of Hybrid Home Automation Systems.

Toward this aim, this study sought answers to the following questions 1) How to create a system that will automate the following: IP-Based Closed-Circuit Television (CCTV), Electronics Door Lock, Fire Detection and Alarm System (FDAS), Lighting System, Electrical Power Outlet? 2) How does the system configure the different home automation devices using fog computing? 3) How does the system maximize its usage using data analytics? 4) How to create a mock-up prototype of a single-story house that will apply the home automation devices? 5) How to evaluate the system using the ISO/IEC (21823-1:2019) in terms of transport, syntactic, behavioral, policy and semantic interoperability?

Review of Related Literature and Studies

Fog Computing

Alrawais (2017) found that the fog computing model identified a distributed computing infrastructure closer to the network edge. It enabled edge devices to run applications locally and make immediate decisions. Moreover, this reduced the data burden on networks as raw data does not need to be sent over network connections. It improved security by preventing sensitive data from being carried past the edge where it is needed and resilience by enabling IoT devices to function when the Internet connection is broken. Additionally, it enables end devices to connect to a local integrated computing, networking, and storage system, including smart meters, industrial sensors, robotic machines, and others. A variety of hardware and software solutions are used in fog computing. Finally, all fog applications take action after monitoring or analyzing real-time data from networked devices.

In a similar study by Flavio (2012), fog computing expanded the cloud computing paradigm to the network's edge, enabling a new generation of services and applications. Low latency and location awareness, wide geographic dispersion, mobility, many nodes, the predominance of wireless access, the presence of streaming and real-time applications, and heterogeneity are the features that best describe the fog. The author argued that the above characteristics make the fog the appropriate platform for several critical Internet of Things (IoT) services and applications, namely connected vehicle, smart grid, smart cities, and, in general, Wireless Sensors and Actuators Networks (WSANs).

Internet of Things (IoT)

With the help of the Internet of Things (IoT), from the study of Ni (2018), billions of physical objects can be linked together to exchange data for a range of uses, such as home automation, infrastructure management, and environmental monitoring.

However, some IoT applications (including augmented reality, smart traffic lights, and home energy management) rely on unsupported IoT characteristics (such low latency, location awareness, and geographic distribution). Fog computing is also used in IoT to extend networking, storage, and processing resources to the network edge, enabling various capabilities. The study also discussed the security and privacy needs for fog computing and provided security and privacy concerns to IoT applications. Finally, the report also outlined potential obstacles to secure fog computing and examined cutting-edge approaches to security and privacy concerns in fog computing for IoT applications.

The Internet of Things (IoT) has created a significant opportunity to create reliable industrial systems and applications as radio-frequency identification (RFID), wireless, mobile, and sensor devices have become increasingly prevalent, according to the study of Zu (2014). There are numerous industrial IoT applications that have lately been developed and deployed. The purpose of the study was to understand the evolution of IoT in industries by analyzing current IoT research, important supporting technologies, significant IoT applications in businesses, and highlighting research trends and impediments.

Home Automation

Home automation has been experimented with by several previous systems, but none of them appear to have been able to provide useful, inexpensive solutions. Vikram (2017) presented that demand for connecting smart devices is real given their widespread usage and reliance on their striking characteristics. The study provided a method for building a Home Automation System (HAS) with Wireless Fidelity (Wi-Fi) at a low cost. This clarifies the concept of smart gadgets talking to one another. The environmental, security, and electrical aspects of a smart, networked home were built in the study to be able to be seen and managed by a Wi-Fi-based Wireless Sensor Network (WSN). The user can easily control the devices in a smart home through the Graphical User Interface (GUI) of an Android application-based smartphone.

Meanwhile, Lohan and Singh (2019) posited that the term "Internet of Things" refers to the interconnection of devices like lights, home automation, and cars with built-in sensors, environmental monitors, and heart monitors that enables these devices to gather, exchange, receive, and send data across a network. The study discussed the use of various sensors in homes, such as temperature, motion, and brightness sensors. The research also contained an algorithm for home air conditioners and energy-efficient lighting. Energy savings of a total of 20.78% were found after comparing energy use before and after the system model was installed.

According to Tekeoglu (2015), there has been a considerable rise in the use of IP cameras in a variety of settings over the past several years, including marketplaces, malls, pharmacies, movie theaters, and schools. Recent devices on the market are cloud-based and send the captured video to a cloud server. Security becomes a major issue as these IP cameras are used more frequently. However, there has not been much improvement in the security of these devices.

This study examined the security of wireless, cloud-based IP cameras. The security of these devices involves several study areas, including secure multimedia, network security, and cloud security.

Inter Protocol Based CCTV

Fleck and Straßer (2018) asserts that Western societies are aging quickly. Seniors' right to privacy must be respected while their safety is automatically monitored around-the-clock. This is an additional illustration of the state-of-the-art video surveillance applications that have recently been discovered in addition to the conventional surveillance security applications at airports, academic institutions, and commercial facilities. The current surveillance systems have three drawbacks. A networked and automated system based on smart cameras addresses these problems. The technology under consideration aims to assess the physical environment and reflect all pertinent information—and only pertinent information—live in an integrated virtual counterpart for visualization.

Fire Detection and Alarm System (FDAS)

Piera (2019) stressed that fires can be seriously destructive to properties if they are not correctly controlled. Because of this issue, fire detection and alarm systems are very crucial. Traditional fire alarm systems, on the other hand, rely on a wiring network, which has problems and restrictions including rigidity in the FDAS layout plan during building construction and challenges during restoration where the removal and relocation of traditional FDAS necessitates additional labor. A wireless sensor network-based fire detection and alarm system was created to solve these issues. The fire alarm control panel, fire detection node, and fire alarm node make up the majority of the FDAS. XBee was utilized as the wireless transceiver to provide wireless communication between the nodes. The mesh routing protocol, which makes the system more reliable and adaptable, is an important feature of XBee.

Muruganand (2015) emphasized that fire security at home and in the workplace is crucial in every situation because everyone needs security, whether they are living in their own home, an apartment, the workplace, a hospital, or a university. To protect people's lives and their possessions, it is imperative that the industry or home has a full fire security monitoring system installed.

Access Controls

According to Nag (2018), a standard security system necessitates the use of a key, identification (ID) card, or password to gain access to locations like a person's home or place of business. However, the existing security mechanism is riddled with holes that allows it to be cast and stolen anywhere. Keys, security cards, countersigns, or patterns are used by most individuals to open doors. The goal of this project is to assist users in enhancing the entrance security of important sites by applying face detection and identification. The four subsystems that make up the proposed system are automatic door access control, face detection and identification, photo capture, and picture storage.

Sahani (2015) showed that the design and implementation of a home security system that makes use of remote monitoring and human facial recognition technology to authenticate visitors and manage door accessibility known as a "smart home security control system," has become necessary. His study discussed setting up a wireless control system and restricting access to it in a home environment to authorized people only. An image processing method based on PCA and a wireless network technology based on ZigBee are used to specifically activate the security system in response to a request. The accessibility of the doors is managed by a ZigBee module and an electromagnetic door lock module working together. Security is a top priority for any household. Numerous attempts have been made to secure the entrance and restrict access to the home in this age of steadily rising crime rates.

Automatic Lighting System

Arjun (2019) showed that most people desire to lead affluent lives filled with modern conveniences. Scientific and technological progress is accelerating to meet the aforementioned needs. Street lights are now operated manually but worldwide this could waste a substantial amount of energy and needs to be altered. The Internet of Things (IoT), with its cutting-edge advancements, has a significant impact on automating a variety of processes, including health monitoring, traffic control, agricultural irrigation, street lighting, schools, etc. Addressing the world's energy issue and increasing the use of street lighting are essential. With the study on smart street lighting systems, the authors also looked at and discussed a number of sensors and IoT components.

According to Adnan (2019), to provide adequate lighting in the home based on human activities for comfort, sight, and eye health. An Arduino microcontroller with a Bluetooth module, light sensors, and an Android smartphone make up this system. The artificial lighting is managed by the dimmer circuit. The technology controls artificial lighting to provide the required lighting by measuring ambient light levels. An application that enables users to indicate their activity was developed using Android cellphones. The IoT-based system's users can choose between up to nine activities. A prototype is built and tested in order to see if the system is workable. The results show that the developed apps enable the user to specify an activity and that the brightness of the light bulb complies with that activity and quite successful at building systems with unshakeable intelligence.

Smart Meter Data Analytics

Due to the widespread use of smart meters, it is now possible to obtain a wealth of accurate data on electricity consumption. According to Wang's research (2019), the deregulation of the power industry has been making steady progress, particularly on the delivery side. How to use the large volumes of data from smart meters to support and enhance the efficiency and sustainability of the energy system is a crucial challenge. Smart meter data analytics has been the subject of extensive research to date. To give a comprehensive overview of the available research and to identify issues for future research, this paper presents an application-oriented assessment of smart meter data analytics.

Synthesis

Researches occasionally innovate and generate the same ideas because technology is an area that is continuously being discovered and thus there is always opportunity for improvement.

Whatever occurs, a certain outcome is always the end consequence. According to the literature assessment, people's living standards rise as IoT regulations get more stringent. The aforementioned local and international literary masterpieces each provided the researcher with additional information that acted as a roadmap. All the literary studies that have been collated and referenced deal with the construction and development of home automation systems and Internet of Things devices.

Technology is given more attention today, and as a result, more inventions are now accessible to the general population with reasonable prices and practical uses. The first step toward technological flexibility is home automation, and in the years to come, there will be more developments in the development stage that might enhance daily life for individuals and support those who need support. Kousalya (2018) stated that combining comfort and simplicity with one system is the purpose of smart home automation solutions. Therefore, developing a smart home automation system would be advantageous not only as a method of boosting user comfort for the aged and disabled but also as a means of producing a cost-effective budget system.

Home automation will require less work from humans because of current technological advancements, according to Malav (2019). Future versions of this kind of study will also be more compact, affordable, and accessible as well as having a higher capacity and a longer lifespan. Technology will now be more adaptable and use less electricity than it did previously, both of which will improve human life. In a hybrid home automation system, fog computing has advantages that have been highlighted by study. By distributing computing resources to edge devices, fog computing offers real-time data processing while reducing latency and speeding up response times. Studies have shown that this method enhances the performance and dependability of home automation systems, particularly for time-sensitive applications like security and alarm systems.

Fog Computing in Hybrid Home Automation Systems: Recently, home automation systems have become more popular because they provide homeowners with comfort, energy efficiency, and increased security. The expansion of networked devices, as well as the demand for real-time processing and low-latency communication, poses challenges for conventional cloud-based designs. Fog computing, a decentralized computing paradigm, has emerged as a workable solution by putting computer resources closer to the network edge. IP-based CCTV and Fog Computing: Integration of fog computing with IP-based CCTV has demonstrated to provide a number of benefits. Local processing of video feeds by fog-enabled CCTV systems enables real-time video analysis, object recognition, and event detection. Edge computing skills are used to do this. This decreases the need for continuous data transfer to the cloud, lowers bandwidth needs, and enables quicker security issue resolution. Fog computing for access controls can reduce the need for a central cloud server by managing local user authentication and authorization through fog nodes placed close to access points. This improves access control response times and system dependability. Fog computing also makes offline access control possible, ensuring that access rights may be reviewed even in the absence of a cloud connection. FDAS and Fog Computing: Fog computing has the potential to significantly boost FDAS performance. By putting edge devices with fire sensors, smoke detectors, and alarm triggers at the network edge, it is possible to provide real-time fire detection and warning. A fog-enabled FDAS can quickly analyze sensor data, identify likely fire incidents, and take immediate action, such as activating fire suppression equipment or alerting locals and emergency services. Lighting control systems and intelligent outlets with fog computing.

In order to improve energy economy and user comfort, fog-enabled lighting systems may change lighting settings based on real-time occupancy and ambient light conditions. Edge intelligence is used to do this. Fog computing-enabled outlets, like smart outlets, can measure local energy use, allowing home owners to monitor and control energy use in real time. Smart meters are a type of contemporary technology that enables real-time detection and monitoring of energy use in homes. By combining data analytics methods with smart meters, homeowners can identify opportunities for energy savings, enhance the efficiency of their electrical appliances, and learn relevant information about their energy usage habits. Research suggests that when data analytics and smart meters are combined, detailed analysis of energy use patterns can be accomplished. By compiling and analyzing data on energy usage, homeowners can discover more about which electrical appliances use the most energy, when energy demand peaks, and how energy usage varies throughout the day. By using this information to make educated decisions about changing device usage, implementing energy-saving strategies, and other concerns, homeowners are able to optimize their overall energy use. Integrating data analytics with a smart meter in the realm of predictive maintenance and fault detection enables predictive maintenance and fault detection capabilities for everyday electronic items. Real-time energy usage information can be used to identify anomalies or odd energy consumption patterns, which may indicate flaws or inefficiencies in the device. By taking proactive steps to identify problems, plan maintenance, and schedule it, homeowners can avoid having to pay for costly repairs or replacements.

In this era therefore, civilization places a larger emphasis on technological breakthroughs, and more inventions would be offered to societies with affordable costs and consumption. The first step in improving technology's flexibility would be home automation. There will also be more developments for the developing stage in the years to come, which could help to improve people's daily lives and support those who need it.

Conceptual Framework

The aim of this research was to design and develop a hybrid home automation system using fog computing that covers the design plan, specifications, and implementations of convergence of IoT devices from different vendors.

Figure 1
Conceptual Framework

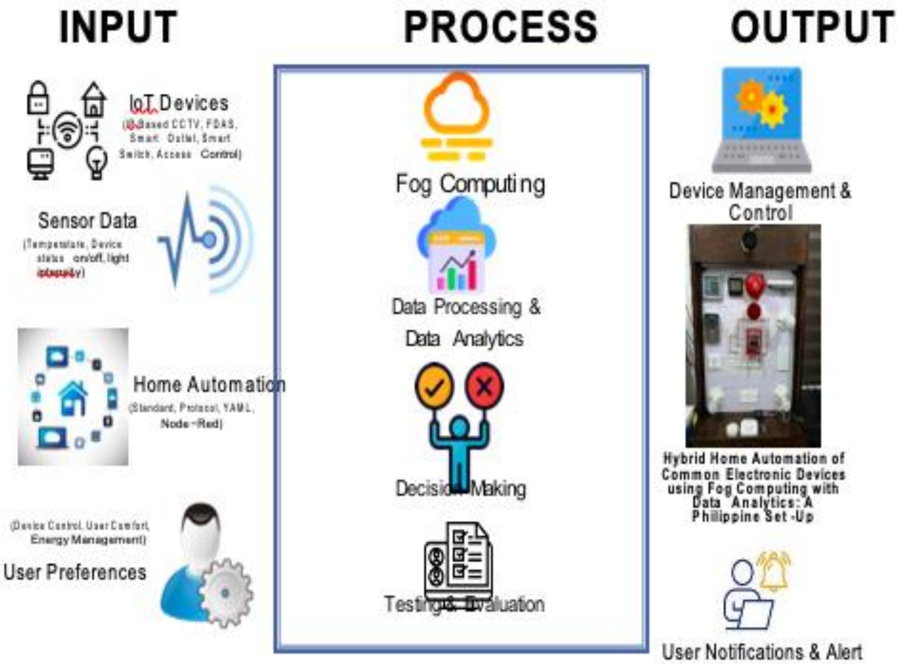


Figure 1 shows the Input-Process-Output (IPO) model utilized in this study. The Input variables are IoT devices in home automation and different communication protocols used by IoT devices. The process was started with the design development of an electronics plan that integrated different systems such as IP-Based Closed-Circuit Television (CCTV), access control like electronic door lock, Fire Detection and Alarm System (FDAS), automatic lighting system and electrical power outlet. Moreover, configurations were done such as static IP assignment and pairing of IoT devices to the central controller. This was followed by script development, testing, and evaluation. The output was the hybrid home automation system of common electronic devices in the Philippines using fog computing. Furthermore, evaluation and feedback were also necessary to check the effectiveness of the system.

Methodology

Quantitative Research Design

The researcher used a quantitative and descriptive developmental research design. This involved utilizing a quantitative method for collecting measurable data and applying statistical, mathematical, or computational techniques to investigate phenomena (Gillaco, 2014). It enables performance assessment, system integration, and optimization, improving the system's effectiveness and user experience. A survey was conducted online using the Microsoft forms and the collected data then imported using the Microsoft excel to easily compute for the mean and then interpreted the results. The study is both descriptive and developmental. The descriptive form of research describes the system evaluation using the ISO/IEC 21823-1:2019 framework for interoperability for IOT systems, which is based on interoperability such as transport, syntactic, behavioral, policy, and semantic interoperability. The goal of the developmental research is to create, specifically for the Philippine context, a hybrid home automation system of widely used electronic devices.

Research Locale

The participants in this study were all from Cavite which is located south of Metro Manila in the Calabarzon region and where a variety of economic activities are happening in both urban and rural areas. Particularly in the Cavite Economic Zone and industrial parks, the manufacturing and industrial sectors contribute significantly to the province's economy. Evidently, the recent development in Cavite has been greatly influenced by the construction of housing subdivisions, condos, apartments, dorms, and other residential developments. This development has been spurred by the province's proximity to Metro Manila and its growing population.

The respondents consisted of contractors, system integrators, homeowners, engineers, and IT experts to fully understand the functionality and interoperability of the system. They came from all eight districts of Cavite as follows.

DISTRICT	**CITY**	**NO. OF RESPONDENTS**
1st	Cavite	4
	Kawit	1
	Rosario	1
2nd	Bacoor	2
3rd	Imus	6
4th	Dasmariñas	14
5th	Silang	1
6th	General trias	3
7th	Amadeo	1
	Tanza	2
8th	Tagaytay	2
	Naic	1
	TOTAL	38

Description of Respondents

The study used Microsoft Forms to distribute survey questionnaires to at least three contractors, system integrators, homeowners, engineers and IT experts who were familiar with IoT home automation. A total of 38 participants– 4 contractors, 5 system integrators, 10 homeowners, 10 engineers and 9 IT Experts.

Sampling Technique

Expert sampling, utilized in the study, is a strategy for sampling employed when researchers select their responses dependent on the researcher's training in a particular field of study (Etikan and Bala, 2017). The study made it crucial to select system evaluators or respondents who have experience with home automation and the Internet of Things. The result was evaluated by the following experts as shown in Table 1.

Table 1
Respondents of the Study

Data

EVALUATORS/ EXPERTS	TOTAL
Contractors	4
System Integrators	5
Home Owners	10
Engineers	10
IT Experts	9
	38

Gathering Procedure

The data gathered from the respondents were assessed by getting the mean of each individual question as well as the mean of the entire questionnaire. Then the mean of each question was added to get the sum of the mean of every question. The researcher used the ISO/IEC 21823-1:2019, with aspects of Transport, Syntactic, Behavioral, Policy, and Semantic interoperability for IOT systems framework that describes a general framework for interoperability of IoT systems.

There are three criteria for each aspects of interoperability with a total of 15 criteria. Using the Microsoft Form, the survey was given to respondents and was gathered by the researcher. Part of the survey was the Video Demonstration of the Hybrid Home Automation System and the 15-item ISO Criteria of Interoperability. The survey was conducted online provided the amount of time given for responses which were open for two weeks. To compute the mean based on ISO Criteria, the responses were imported from Microsoft Forms through Microsoft Excel. The researcher tallied the responses' ratings of 5, 4, 3, 2, and 1, and divided the number of overall respondents.

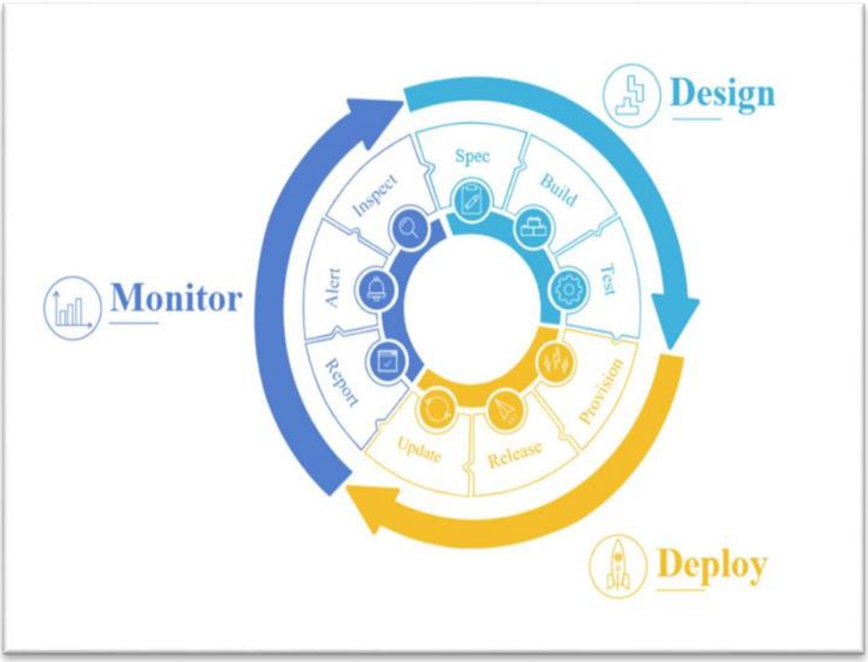
Software Design

Software design entails the development of a system that seamlessly integrates home automation, fog computing, and data analytics to enable effective and intelligent management of electronic devices within a home environment. This involves key components such as the home automation controller and fog nodes. In terms of connections, the controller interacts with fog nodes to oversee local device control, with the fog nodes responsible for collecting and processing data locally. The user interface provides a platform for users to observe and manage devices, access analytics outcomes, and configure preferences. Concerning interface design, a mock-up prototype was created, displaying connected devices, real-time status updates, and analytical insights. Users were afforded controls to establish automation rules, preferences, and monitor energy consumption. In the device interface, standardized interfaces were employed for various electronic devices (lights, appliances, sensors) to guarantee seamless compatibility.

Project Development

The IoT Wheel Development below shows the step-by-step process of how the researcher used to manage complex software and product development.

Figure 2
IoT Wheel Development



(https://niolabs.com/enterprise/iot-wheel-project-life-cycle)

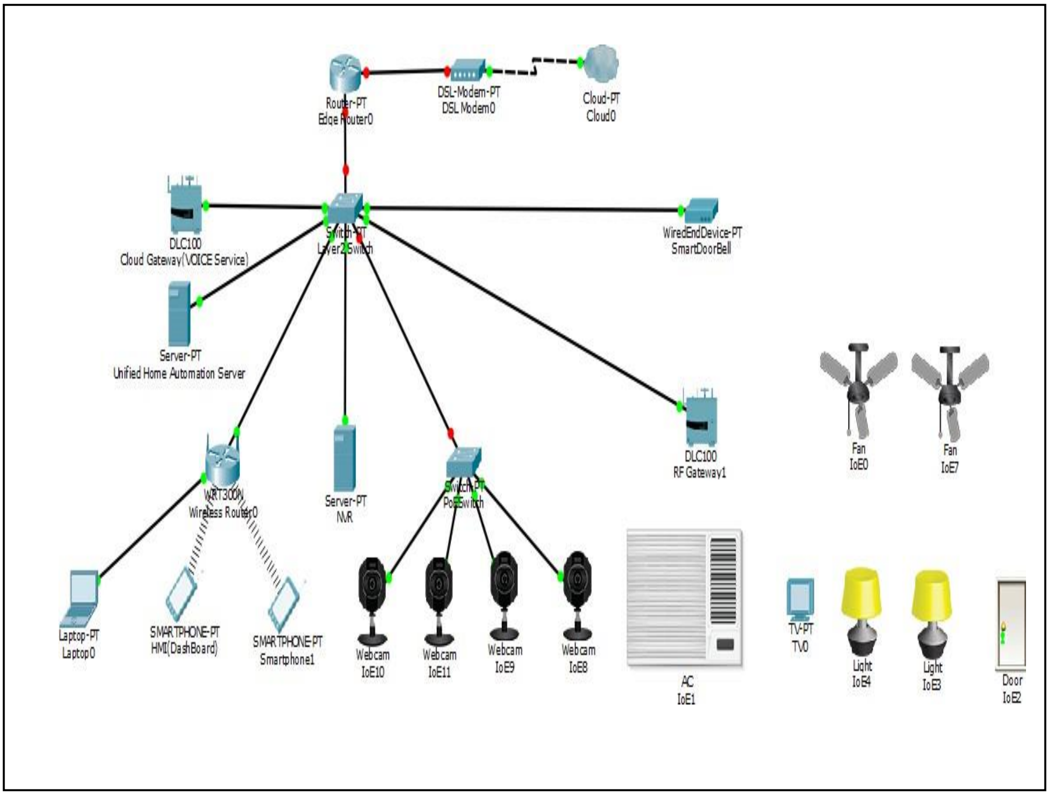
The IoT Wheel in Figure 2 is a closed-loop project cycle that enables iterative creation and correction as needed or as issues arise. The cycle perspective is crucial since IoT systems are made up of so many interconnected components, each with its own cycle, according to Nio, Inc. (n.d.). The cycle view helps identify less obvious issues that arise over a system's cycle. A product or system's life cycle is the sequence of stages it goes through from conception to demise.

Design Model

The design is tailored to the different systems that are commonly found in home automation systems, such as IP-Based Closed-Circuit Television (CCTV), Access control, Fire Detection and Alarm Systems (FDAS), Automated Lighting Systems and Electrical Power outlet.

Figure 3

Logical Topology



The logical topology which was the basis of the hybrid home automation is shown in Figure 3. This study was limited to at least three different brands to investigate the compatibility of various devices. The burglar alarm system and the power outages are not included in the proposed study. The system testing was only conducted on a mock-up of a single- story house. The system also used a home router with an IEEE802.11b/g/n standard only.

Equipment Analysis

The list and prices of each material needed for the system are shown in Table 2. Each material's cost is set by the seller at the point of sale. In order to ensure that they could be used in the system and that it was of excellent quality, the researcher evaluated the electronic gadgets that are currently available and could be integrated into home assistants and checked the pricing.

Table 2
Cost Matrix

ITEM	DESCRIPTION	BRAND	UNIT_PRICE	QTY	Amount
1	3 Gang Smart Switch	Tuya	2,000.00	1	P2,000.00
2	1 Gang Smart Convinient Outlet	Tuya	2,000.00	1	P2,000.00
3	Smart Thermostat	Tuya	3,000.00	1	P3,000.00
4	Siren	Tuya	1,500.00	1	P1,500.00
5	Sonoff Bridge Zigbee	Sonoff	1,500.00	1	P1,500.00
6	Sonoff smart switch zigbee	Onoff	1,500.00	1	P1,500.00
7	Sonoff smoke detector	Onoff	1,500.00	1	P1,500.00
8	2MP IP-Based Camera	Dahua	2,000.00	1	P2,000.00
9	Manual Pull Down switch	OEM	800.00	1	P800.00
10	Sound Bell	OEM	1,000.00	1	P1,000.00
11	Fire Indicator Light	OEM	1,000.00	1	P1,000.00

12	Access Control	OEM	4,000.00	1	P4,000.00
13	220Vac Buld	OEM	300.00	3	P900.00
			Total		**P22,300.00**

Research Instrument

The research instrument that was used in the evaluation of the system was a survey questionnaire with a 5-point Likert scale guide. This consisted of questions that would allow the experts to evaluate the system based on its Transport Interoperability, Syntactic Interoperability, Behavioral Interoperability, Policy Interoperability and Semantic Interoperability.

Statistical Treatment of Data

As shown in Table 3, a 5-Point Likert Scale was used to measure the level of agreement on the given questions. The level of the scale is as follows: (1) Strongly Disagree, (2) Disagree, (3) Neither Agree or Disagree, (4) Agree, (5) Strongly Agree. The 5-point scale is ideal for market researchers, who utilize it to gather replies. The researcher decided to use this scale because it is best for recording opinions on services/products which the user has used/experienced.

Table 3

Five-point Likert Scale

Likert Scale Description	Likert Scale	Likert Scale Interval
Strongly Disagree	1	1.00 – 1.80
Disagree	2	1.81 – 2.60
Neither Agree nor Disagree	3	2.61 – 3.40
Agree	4	3.41 – 4.20
Strongly Agree	5	4.21 – 5.00

Testing and Evaluation Procedures

For the testing and evaluation procedures, based on the system understanding and requirements analysis, the researcher, acquired a comprehensive understanding of the hybrid home automation system and its intended functionality that identified the common electronic devices needed such as the IP-Based CCTV, FDAS, lighting system, access controls and electronic power outlet and each device integration requirements. The researcher also defined the performance expectations, security considerations, and user experience requirements. The test planning was part of the procedures that developed a test plan outlining the objectives, test scenarios, and test cases, furthermore, the researcher determined the required hardware, software, and network infrastructure for testing, the metrics, and criteria for evaluating the system's performance, reliability, and security.

The test environment setup was conducted which mimicked the target deployment scenario and which installed and configured the necessary hardware components, such as fog nodes, gateways, and electronic devices. Finally, the researcher configured the fog computing software stack, including the fog nodes, fog orchestration, and communication protocols.

To test the functionality of the system, between fog nodes and electronic devices, the researcher carried out device connectivity, communication protocols, and data synchronization which verified the usability of user interfaces and automated rules. Performance testing was also included in the testing, where the researcher evaluated how well the system performed under various loads and circumstances. This allowed for the evaluation of how quickly and slowly the system responded to fog computing activities like processing data and making decisions. By boosting the number of linked devices and keeping an eye on resource usage, the system's scalability was also evaluated.

For the Reliability and Resilience Testing, the researcher evaluated the system's ability to respond to failures and capacity to recover gracefully. To monitor the system's behavior, the researcher simulated network outages, fog node failures, and device disconnections. The user also assessed the efficiency of data redundancy, failover techniques, and fault tolerance measures. The hybrid home automation system was put through security testing as well, which included evaluating data encryption, access controls, authentication methods, and secure communication protocols as well as performing vulnerability scans and penetration tests to find any potential weaknesses.

To evaluate the system's usability and user experience, user experience and acceptance testing was performed, the researcher identified those who participated end users or representative testers to assess the usability and user experience of the system, including contractors, system integrators, engineers, IT Experts, and homeowners who gathered comments on the system's interface, functionality, and general satisfaction. The researcher used the user feedback to develop and refine the system after receiving feedback. In order to analyze and evaluate the data, the researcher compared the findings to predetermined performance standards and criteria. Areas for improvement and potential system enhancements were also suggested. For the reporting and documentation, the researcher wrote a thorough test report that included a summary of the testing procedures, results, and suggestions.

Results and Discussion

In order to answer problem 1, steps 1 to 3 are applicable for all the devices that differ in their components, requirements and the vendors. For step (1) identifying the components: the researcher made a list of all the electronic hardware, such as sensors, actuators, controllers, communication modules, and other hardware, that needed to be integrated. Since the electronic devices have been identified, the next step was to determine which components are required for integration. For step (2) defining the requirements: each component's particular needs, including those for power, communication protocols, and compatibility with other components, were established. For step (3) choosing the vendors: the researcher assessed, studied, and double- checked a variety of vendors and suppliers to see who offered the required components. Internet protocol, or IP, cameras that record video and convert it into digital signals are the system's essential components and prerequisites for operation. CCTV systems using IP technology are wired to the network. The IP cameras must be connected to the network infrastructure, which consists of switches, routers, and cabling, in order for data to be transmitted over the network. Since IP cameras require power, Power over Ethernet (PoE) technology permits the transfer of both data and power over a single Ethernet cable. This simplifies the wiring and makes installation easier.

In order to answer the problem 2, the researcher followed steps 1 to 6 to fully explain how system configurations take place.

Step (1) Selecting the devices: First, the required IoT home automation devices were selected based on the desired functionality, features, and compatibility with other devices.

Step (2) Installation of the devices: The devices were physically installed in their intended locations like for the study, using a mock-up design model. This involved installation of each electronic device in the pre-build wood frame, following the manufacturer’s instruction’s installation instructions. Each device must be set up as directed by the manufacturer user’s manual and connected to a power supply.

Step (3) Connecting to the network: each device was connected to the home network, either through different communication protocols like Wi-Fi or an Ethernet cable.

Step (4) Configuring the settings: the settings of each device were configured according to the desired preferences.

Step (5) Testing the devices: the devices were tested to ensure that they were functioning correctly and that they could be controlled.

Step (6) Troubleshooting issues: any issues or errors encountered during configuration were identified and resolved, by resetting the device.

Data analytics can be highly beneficial in this that makes use of fog computing by extracting important insights and improving the performance and efficiency of typical electronic devices. The researcher of the study ensured the following steps.

Step (1) Setting up a Wi-Fi smart meter: Installation of a Wi-Fi smart meter in the mock-up design model. This device collected data on energy consumption and provided insights for optimizing device usage.

Step (2) Connecting electronic devices to the Wi-Fi smart meter: this allowed the meter to track their energy consumption patterns and collect relevant data.

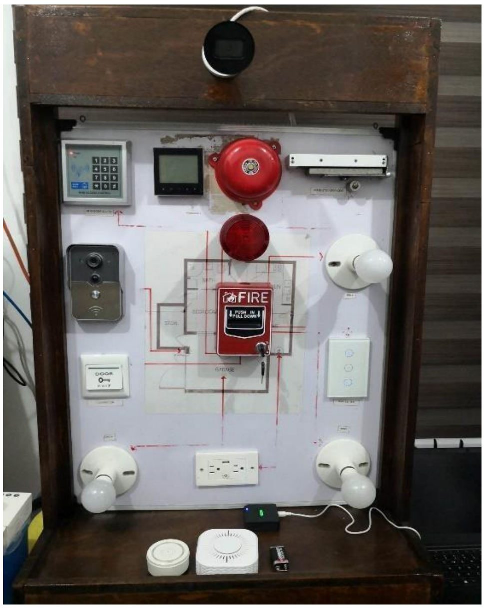
Step (3) Collecting energy consumption data: the smart meter continuously collected data on energy consumption from the connected devices.

Step (4) Analyzing the data: using a 3rd party mobile application, the Tuya App, the researcher analyzed the data with the use of data analytics tools and techniques to analyze the collected energy consumption data via the expense management and also the daily, weekly or monthly electricity statistics.

Step (5) Adjusting device usages: The history card gave the user the history logs that consist of the start date and end date where the devices were being activated or controlled by the user.

The researcher of the study integrated all the approaches of problem numbers 1, 2, and 3. As shown in figure 4, the mockup prototype design model as well as by following the steps, a mock-up prototype was successfully created for a single-story house that applied home automation devices. The prototype was tested, refined, and documented to ensure that it was both functional and user-friendly.

Figure 4
Mock-Up Prototype System



The study also included the evaluation of the system using the criteria that were set by the ISO using the Transport, Syntactic, Behavioral, Policy, and Semantic interoperability for IOT systems framework (ISO/IEC 21823-1:2019) which described a general framework for interoperability of IoT systems. The data was gathered by the proponents using Microsoft Forms. The weighted average was used in measuring the respondents' evaluation of the system using Likert scale surveys. Table 4 contains the mean per category and the overall mean of the entire evaluation which is 4.78. An excellent rating is given to each category. Each category garnered mostly an excellent remark using the 5-point Likert scale which indicates that the system does not need more changes and that it is functioning to be used by the respondents. This means that all the respondents strongly agreed that the five categories of interoperability met all the standards and criteria.

Table 4

Overall Results

Category	Mean per Category	Description
Transport Interoperability	4.80	Strongly Agree
Syntactic Interoperability	4.81	Strongly Agree
Behavioral Interoperability	4.81	Strongly Agree
Policy Interoperability	4.75	Strongly Agree
Semantic Interoperability	4.73	Strongly Agree
Total Mean:	4.78	Strongly Agree

Due to the growing popularity of home automation systems and the potential benefits of fog computing, many smart IoT devices benefit from effective, efficient and manageable communication made possible by fog computing. As compared with cloud computing, fog offers a variety of solutions for latency-sensitive, home automation and even industrial IoT automation that includes data transmission, virtualizations, segregation, and monitoring.

As for the components used, in electronic door lock the researcher used an RFID reader for the door entry to control access. Its main task is to read user input from a tag or using a keypad that is handled by authorized people. From the RFID tags, it extracts the distinctive identification data. For the FDAS manual pulldown switch, main processing hub is the control panel and inside the panel, Sonoff smart switch was installed to control the main power devices in the system like the fire alarm and the fire bell. For the automatic lighting system, the researcher used the lighting fixtures, with a 60-watt light bulb or the standard bulb available in the market. The system requires appropriate wiring and WIFI communication infrastructure to connect the components.

As for the configurations of IoT devices, the researcher studied each IoT devices and selected based on the desired functionality, features, and compatibility with other devices, depending on each IoT brands. Following the manufacturer's instructions for installation, each device must be set up as directed by the manufacturer user's manual and connected to a power supply. Different Communication protocols were used to connect to the network.

To expand the management of the electronic devices using data analytics, the researcher carefully analyzed what particular device to use and identified requirements suited for fog computing. In a hybrid home automation system that utilizes fog computing, the researcher set up a Wi-Fi smart meter, and installed a Wi-Fi smart meter in the mock-up design model to track the devices and collect data on the energy consumption.

In order to develop a mock-up prototype design model, the researcher meticulously analyzed and strategized for both the architectural and technological facets of the system. The researcher established the integration of components, configurations, communication protocols, and compatibility, all contributing to the creation of a successful mock-up prototype design.

Hybrid home automation with fog computing is a necessary technology for modern homes as it offers numerous benefits. It provides an efficient and reliable automation system that enhances the security, safety, and convenience of home living. By combining fog computing with home automation, the system can process data quickly and effectively, even when internet connectivity is limited. This ensures that the system remains operational at all times, without depending on the cloud for data processing. Additionally, it allows for more personalized and intelligent automation, as the system can learn from the user's behavior and preferences. The robustness of the research is evident in the successful implementation of the hybrid home automation system and the positive outcomes achieved.

Conclusion

In conclusion, this study addressed the issue of automating a number of systems, including IP-Based CCTV, Electronic Door Lock, Fire Detection and Alarm System (FDAS), Automatic Lighting System, and Electrical Power Outlet through a step by step organized manner. The system was then thoroughly tested to verify appropriate operation and error-free interoperability between the parts. Attempts were undertaken to improve the design, changing the choice of components, communication protocols, or power management for greater effectiveness.

The study demonstrated how to configure home automation devices utilizing fog computing using several steps. The study highlights the significance of careful device selection, appropriate installation, network connectivity, configuration, comprehensive testing, and troubleshooting for the effective deployment of a reliable and integrated home automation system.

Recommendations

In this study, the researcher demonstrated how fog computing makes hybrid home automation of common electronic devices more usable and available. However, based on the comments received and the testing done, there are still improvements that can be made such as those involving detailed hardware and software descriptions, scalability, and advanced data analytics techniques. It is recommended to utilize a dependable network connection, as fog computing heavily depends on internet connectivity and the communication between devices. Despite these limitations, the research provides a solid foundation for future studies in the field of home automation and data analytics, especially in the context of the Philippines. Finally, a full documentation of the research methodology and the completed system architecture served as a useful tool for troubleshooting and upcoming improvements.

Limitations

This study effectively illustrated a methodical approach to automating various systems, highlighting the significance of careful component selection, stringent testing, and ongoing improvement for the creation of an effective and integrated home automation system. Also, infrastructure optimization in the Philippines should be customized to address the nation's distinct infrastructure problems. The limitations of the study are attributable to the rapid development of technology and the possibility of some system components becoming outdated quickly. Some electrical devices may not connect with the system seamlessly, which presents possible compatibility difficulties. Moreover, power outages are not included in the system because they can disrupt both online and offline components, cause inconsistencies in the state of the system, and create safety concerns for critical components such as home security systems.

Practical Implications

The study emphasized the advantages of the hybrid home automation system which should enhance the convenience and efficiency that users can enjoy. Additionally, a variety of respondents' well-executed real-world scenarios demonstrate how the system can improve overall user experience by streamlining tasks.

Acknowledgment

Acknowledgements to Dr. Alberto T. Paala, Jr, Graduate School Dean, and Dr. Ma. Corazon Huelar, Graduate School Research Coordinator, to my dissertation adviser, Dr. Joan Lazaro and my panel members, Dr. Nelson Rodelas, Dr. Alexis John Rubio, Dr. Henry Dyke Balmeo, Dr. Shirley Moraga and Dr. Maria Amelia Damian for sharing their expertise.

Sincere appreciation to the Administration, the Center for Innovative Learning Programs (CILP), the University Research Office (URO), the Board of Trustees of Parents Organization of De La Salle University-Dasmarinas Inc. (POLCA) and faculty members of the Information Technology Department of De La Salle University – Dasmarinas, to my friends and colleagues for their support and encouragement.

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