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Research Article

Centralized Management IoT Platform

António Rodrigues[1] *

[1] ISCTE, Lisboa, Portugal
***Corresponding Author:** antoniojr82@yahoo.com.br

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ABSTRACT

On information technology topics, the word "innovation" is increasingly present every day. Regarding the Internet of Things (IoT) subject, it's no different. Every year new IoT products and services are created and presented that allow users to make their lives easier and simpler, connecting people to devices remotely and automatically, generating mobility and operability of services through the heterogeneity of devices connected to the internet.
Based on obstacles found in daily homes, this paperwork aims study the development of a unique and easy use platform. On this platform, it is possible to have IoT devices centralized on the same local network unit so that they can be managed and manipulated through a simple and intuitive graphical interface. Thus, management is unified and practical for any type of user who is interested in using this technology.
In this thesis, good practices and the best solutions researched within the practice of IoT management were studied in different scenarios. Covering types of technologies, proposed architectures, configuration processes and compatibility analysis of features and functionality of different devices currently on the market. Thus, this work aims to present in detail the study of the prototype of a unified platform that allows configuring, monitoring, and managing the integration between heterogeneous devices currently on the market for residential users.

Keywords: Future Internet and Digital Ecosystems, Service Science Management and Engineering, Cloud Computing, everything as a Service (XaaS).

INTRODUCTION

The purchasing of devices with Internet connection functionality has grown exponentially in society. Technological advances and the low cost of these services have helped the popularization and diversification of these devices (Vasseur and Dunkels, 2010). These objects, with the ability to interact with users through sensors allow generating responses and information according to the needs of everyone. These types of devices have been termed IoT (Internet of Things) (Gubbi et al., 2013). The basic concept of the IoT devices' functionality is the presence of RFID (Radio-Frequency IDentification) sensors, tags and readers in telephones, home robots, smart lamps, home appliances connected to the internet, etc. (Atzori et al., 2010). All this infrastructure generates a database of information that allows the user to interact intelligently and in a personalized way with the device. Thus, the home user can have tasks of automated routines, better precision in decision making and interactions between the devices and the servers to which they are connected (Evans, 2011).

The use of this emerging technology has provided many challenges in the scope of management and integration of smart device services, as mentioned by (Atzori et al., 2010a). This technology has as main challenge the interconnection of a group of totally heterogeneous devices. Therefore, each one has its specific protocol and technological infrastructure for each manufacturer. Another relevant factor in the complexity of using IoT is the accuracy of the information. The set of data generated by the sensors of the devices can generate an inaccuracy of information between 60% to 70%, causing insufficient or unnecessary responses for the user (Ma et al., 2013).

Motivation and Research Objectives

The application development for IoT devices is an increasing study area. Currently, there are multiple pieces of research carried out in the scope of smart device management. However, there is still great difficulty in the usability and practicality of the operation of these devices. Therefore, the main purpose of developing this article is to expand knowledge to reduce the complexity of handling this tool for home users developing a brand-new application (Chen et al., 2014). Thus, the focus of this study is based on analyzing and solving the following listed problems:

- **Administration interfaces centralized:** for each device added smartly to the home network, it presents a different application to perform the devices' configuration. When there are few devices, management is possible, but the environment where the user has countless devices on the same home network is becoming a complex factor to manage. (Chaqfeh and Mohamed, 2012)

- **Simplicity in installation and configuration:** the applications of IoT devices, present a series of configuration and installation steps, in a way that requires the user to have technological the knowledge to be able to install and configure. Thus, create a limitation in the use of technology. (Chaqfeh and Mohamed, 2012)

- **Interconnection between devices in a heterogeneous environment:** each device has its application with access to its data. Thus, there is a limit of information and complexity in the computing environment because there are several technologies that are not connected. Thus, it is possible to reduce processing and increase excessive data traffic on the network, as there is no communication between the devices. (Chaqfeh and Mohamed, 2012).

CONCEPTS DEFINED ON IoT TECHNOLOGIES

The term internet of things (IoT) was coined in the late nineties by technological researcher Kevin Ashton in one of his conferences (Ashton, 2010). The concept of this emerging technology is the interaction between electronic devices connected to the internet, thus the internet of "things" denominated today by smart lamps, appliances with computer systems, security systems with sensors, etc., thus, these objects became known as smart devices (Atzori et al., 2010). All interaction between IoT objects is done through the internet, collecting information and data for more accurate and appropriate decisions for the user (Marotta et al., 2013). Some characteristics of these interactions, to exemplify such behavior, are the detection of physical phenomena such as temperatures, light and humidity through sensors, computational capacity to analyses data and send response regarding a certain behavior, identification of physical objects, through format, size, or movement, among others (Miorandi et al., 2012).

IoT Management

According to Cisco, a technology and infrastructure development company, smart device technology is on the rise in the market, and estimated that by the end of 2020, 50 billion smart devices can be reached in the world (Evans, 2011). However, this great demand for interconnected smart devices results in a high need to have more complete and detailed management of these devices, to reduce their complexity (Yin et al., 2020). IoT management systems must consider security factors as a very important pillar to be researched to prevent access by unknown devices, data leaks, security changes, and so on. According to (Delicato et al., 2013), IoT management systems need to have a dynamic feature in the identification of objects to avoid the pre-definition of device configurations, thus making potentiation the safety factor that is essential in this type of technology. Besides the security issue in IoT management applications, other points are very important to be considered and implemented, according to Chaqfeh (Chaqfeh and Mohamed, 2012). Scalability brings the possibility of expanding the technology and the functioning of the application's functionalities. It helps in the dynamic and easy functioning of device activations. From the point of view of data science, the important thing is the treatment of information, to make the devices work properly and allow them to have the most assertive response possible to users. And finally, interoperability in heterogeneous environments where devices of different characteristics, brands, and functionalities are present so that they can communicate without much complexity. The lack of standardization and definition of this type of technology greatly increases the complexity and interoperability of smart devices. Because each IoT application presents a unique data structure to adopt different programming models that are not compatible with each other. Thus, it is necessary to create a set of data structures for the environment of smart devices that are called reference architectures. These architectures have the characteristic of facilitating and guiding the standardization of systems development for this technology (Nakagawa et al., 2011).

IoT System Architecture

The reference architecture, by definition, is the composition of one or more reference models, to allow standardization, avoiding the ambiguity of information unifying business rules, structuring systems architectures, creating good software development practices, and alignment of hardware operation. Thus, the main objectives of the reference architecture can be achieved. The main objectives of the reference architecture according to (Nakagawa et al., 2011) are to facilitate software development, enabling time optimization and construction reduction and testing. Architecture systems standardization, to establish a reference architecture in terms of essential elements to define guidelines, integrations, and compatibility between totally different systems. And finally, manage the evolution of existing systems, allowing to create a natural process for the evolution of new features without impacting those that are currently running. The IoT reference architecture model (IoT-A) developed by a researcher group from Europe and Brazil (Kramp et al., 2013) was a project created in the context of the development of a European IoT reference architecture. This architecture is based on the construction of set key characteristics, defined at a high level of abstraction, allowing a broadly dynamic view that can be used in any phase of the project, from functional development to production. The functional vision defined in IoT-A architecture, has nine groups of functionalities, namely: (i) application; (ii) management; (iii) service organization; (iv) IoT process management; (v) virtual entity; (vi) IoT service; (vii) security; (viii) communication, and (ix) device.

IoT CENTRAL HUB PROJECT

The impact of IoT technology in the market has been increasing every day. It brings countless benefits to users of functionality types, such as ease of collecting information from the local environment (temperature, location data, etc.), handling devices remotely, agility in daily household activities, automation of tasks, monitoring the behavior of features easily, and so forth. Thus, IoT Central Hub brings this whole concept encapsulated in a simpler and easier way for home users. Although there are already numerous applications that allow having the same behavior as the IoT Central Hub, most device management platforms still have high installation and usability complexity, so the main objective of IoT Central Hub prototype is to strongly reduce complexity, allowing more flexibility to the home user as on the market there is still few applications available. The automatic management platform of the IoT Central Hub already meets some main requirements of application type, such as heterogeneity, extensibility, privacy, and usability. The IoT Central Hub prototype must meet the following key system requirements: (i) known protocols in the market: it is recommended to use protocols technologies and platforms already existing in the market and recognized in the computer network area. (ii) Environment identification devices: it is expected that the application automatically identifies the devices that are available and visible to the IoT Central Hub automatic management application. (iii) Installation and automatic configuration: through the devices already identified by the application, it is recommended that an initial connection be made where data authentication is performed by the local connection (local network or Bluetooth) and the installation started if it is the first connection and the configuration of the new connected device. (iv) Device management: it is recommended that the platform is able to manage the devices found in the environment, being able to manipulate the data and control the devices. (v) Definition of data and information model: the application must provide a data and information model for the supported devices, in this way, the data model will facilitate the programming devices used by different manufacturers.

The platform provides the devices' identification through wireless technology connectivity, such as cableless networking and Bluetooth as already mentioned, so in this way, when device searching is started, it looks for available devices in the vicinity for an approximate time of 3 minutes. At the end of this time, the application ends the search and lists all devices found nearby and displays those available to initiate a connection. IoT Central Hub application considers the heterogeneity of devices, allowing connectivity from different manufacturers without having to be linked to a single brand in the market. As such, the platform does not require additional application installations from each manufacturer, as is often required when purchasing a brand-specific device. The prototype developed for managing IoT devices is carried out through an application running on mobile devices, developed in Java programming language, using the integrated development environment (IDE) Android Studio to create the functionalities of IoT Central Hub, as well as the user interfaces created to optimized performance, comfortability, and usability to everyone, without any expertise on computer technology. Regarding the platform's data model and information structure, the application aims to create standardization in data format and communication between the developed application and the connected devices. Thus, device identifier and connection status are examples of data structure characteristics used for device management. To allow wide integration and extensibility of the application with other systems, the prototype of IoT Central Hub uses the most common protocols and standards among developers for the structure of data models such as XML and REST. The simplified communication and well-defined data structure are the main characteristics of IoT Central Hub application development, being one of the biggest enablers of the project to create a simple and easy-to-use environment for the home user.

IoT Central Hub Architecture

The IoT Central Hub management platform architecture is composed of a smart device and a developed smart device management application. The IoT Central Hub application does not need intermediary hardware to perform a connection gateway with the devices, making it easier to connect to the devices automatically. In addition to simplicity in connecting devices, the other point that benefits this type of architecture is the additional cost to purchase a gateway device for every manufacturer in the market. Thus, avoiding an unwieldy accumulation of additional apparatus for the management of IoT devices. The IoT Central Hub application platform is composed of layers that allow data go to through efficiently and structured within the application. As shown in **Figure 1**, the IoT Central Hub application architecture is structured in three layers: Application, Services, and Communication.

Application layer: it is the initial layer where the user has visibility of the operation and the autonomy to manage the IoT Central Hub platform through the graphical interface, in a fast and intuitive way. **Service Layer:** application's intermediate layer is formed by the platform's services. The services interpret the data for the correct functioning of events and provide support for device connectors to establish the connection efficiently for data processing. **Communication Layer:** it's the layer where exist network communication protocols, Bluetooth, and wireless networks are used at that moment. These protocols are used to encode and identify data transferred through the types of protocol versions that the application supports.

The IoT Central Hub platform data communicates with the other device through the gateway on both sides to maintain system reliability. Thus, after pairing the devices, through the data structure configured in the application, the communication is carried out by parameters that are sent from one gateway to the other. In way, the application can work as a server and send the instructions to another device without having to configure or install any version from a specific manufacturer. Thus, the application allows the user to change or adjust any functionality of the applications already installed on the other device.

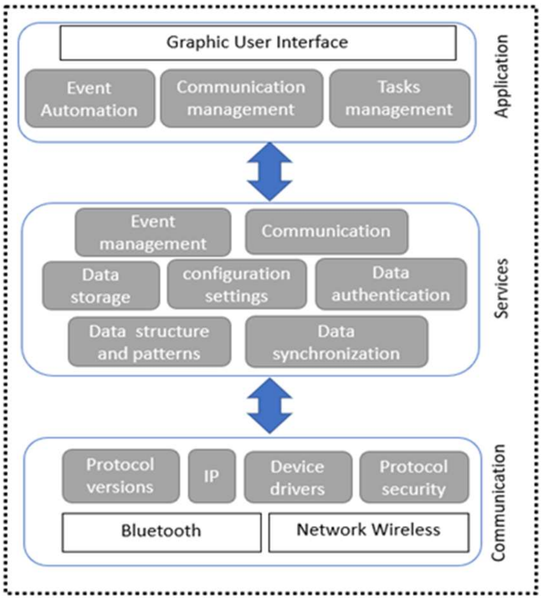

Figure 1. IoT Central Hub Application Architecture

Figure 2 exemplifies the functionality of sending parameters between gateways in two different scenarios, where the one is composed by soundbar (model Ematic ESB210) and the application of the IoT Central Hub installed on the device, in scenario A. In scenario B, it is composed of a security camera (model IMILAB C20) and an IoT Central Hub application installed on the device. In the case of the prototype developed for the IoT Central Hub application, the functionality designed was the verification of the battery status in a remote device.

IoT Central Hub Functionalities

The IoT Central Hub application is composed of five main features that were mentioned previously throughout this research work. The main functionalities of the developed work are turning the communication interfaces on and off, making the device searchable to be identified by another device, seeing the list of paired devices, searching which devices are visible, and sending configuration parameters to the destination gateway. Each functionality has a specific feature that allows the proper device management platform to function. To the prototype elaboration, models of smartphones from the manufacturer Samsung were used, one was a mobile Samsung Galaxy A41, and another is a Tablet Samsung Galaxy Tab S6. The application developed to manage the devices, it was installed in both devices, named IoT Central Hub through an executable ".APK" that runs automatically as soon as it is started, without any further configuration by the user. Through the five basic application functionalities, it is possible to perform connection, pairing, searching, and becoming searchable, and sending parameters, as shown in **Figure 3**. The first functionality to be explored in the application is the connection availability environment. Connectivity between devices must always be active to allow access to data through the wireless communication interface. As previously mentioned, the prototype limited itself to using Bluetooth connectivity and left the other connection option, Wi-Fi connectivity, for future work. However, the prototype has already left a research path open to continue this type of connection in the future studies. Bluetooth connectivity was used Bluetooth Low Energy (BLE) technology, which is a more appropriate technology for IoT devices, as they consume less energy and are more efficient in operation. Due to the use of this technology, it is recommended to use Bluetooth version 4.2 or higher to have a better data transmission rate.

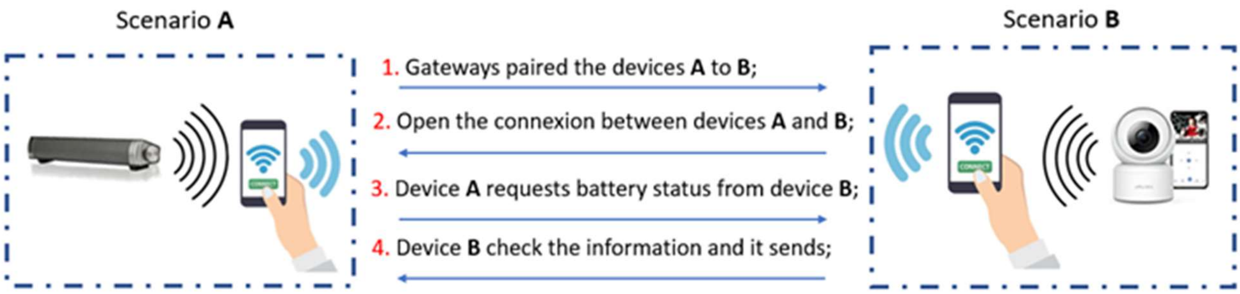

Figure 2. IoT Central Hub Data structure communication

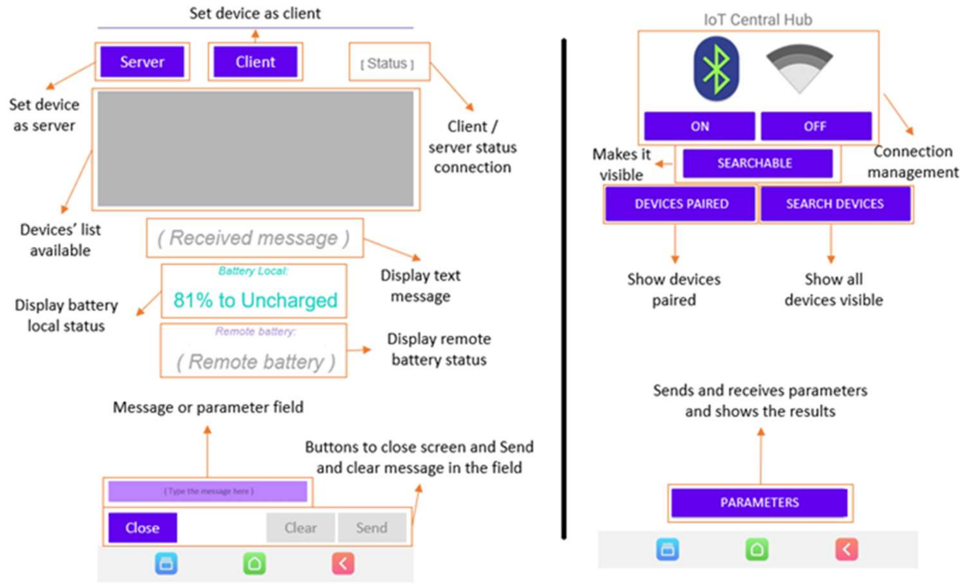

Figure 3. IoT Central Hub functionalities

The Paired devices functionality allows checking all devices that have been connected to the IoT Central Hub platform. Thus, it is possible to identify the list of devices allowed to perform parameters requests for managing the other device. When a command is triggered, a list of devices is shown, but for security reasons some devices omit that information, and it is not completely identified. Sometimes the name of the application is not identified, for privacy reasons, and only the MAC address of the devices is displayed. The functionality of sending parameters is the most complex compared to other developments on the IoT Central Hub platform. This function is intended to be the principal added value to future developments. This function opens a line of research to explore numerous possibilities to add new functionalities and enrich the IoT Central Hub application even more. For the development of the functionality of sending parameters, it was necessary to create an additional screen to allow better usability to the user and brings better benefits to the application. Thus, as shown in **Figure 3**, it is possible to identify the features developed for sending messages and new parameters to the connected device. In addition, you can automatically check the battery level function already added to the application that the local device is automatically identified. Then, when a new device is connected, it is updated with the battery level information of the new device. On the second screen developed to IoT Central Hub platform is the main functionality of the application, sending a message to the remote device, checking the battery status of the local and remote device, and sending parameters to the others.

IoT Central Hub Evaluation

The evaluation and testing of the interviewed users occur with no prerogative, no explanation, to check if the application is intuitive for all users, regardless of their area or expertise. After the first contact with the platform, if the user faced any obstacle that made the user blocked, the developer intervened in the test and explained the operation, giving them assistance to be able to continue with the tests. After this first contact, a new attempt was made to see if users had no difficult to use the application after being provided some details of the proper functioning and environment for handling the application. In addition, the time was controlled to realize how long it took the user to be able to use the application in an intuitive manner. After, the same time was timed to identify how long the user could perform the same activity on the same time slot, but now, as prior knowledge of the application. The time control supports to realize the usability and agility that IoT Central platform should have, demonstrating its efficiency and effectiveness in using a new technology to the users who have never had any contact before. As shown in **Figure 4**, IoT Central Hub platform usability evolution could be analyzed, according to the instructions provided to users. The initial contact and without any further information about the platform how to use it, the application was available to respondents to be installed on their devices. The only information provided to the participants was that they need to have two devices to make the application work and superficial summary of the application's purpose, nothing else was informed to understand what the difficulty would be to install and usability of the application. Regarding installation, one hundred percent of participants were able to install correctly and intuitively, confirming that application is easier to install through ".APK" file (extension defined by Android as executable), thus, there is no obstacle or installation error.

Another relevant point to the research is the types of devices used by users. The only recommendation was that there were two devices running Android operating system to work application properly. Later, the user did all the work without any intervention. After installation, the user moved to the next stage of using the application, connecting, and using the functionalities available in IoT Central Hub application. As can be noted in **figure 4**, the amount of people who classified the application easier to use, they are between groups one and two when they did not get any explanation. However, after explaining the use and the interference during use, participants in groups three and four performed better.

Figure 4. Survey result – Application usage time

Although respondents belong different areas and some of them, non-graduation degree, the result was balanced. Also, regarding the gender of the participants, in general, men and women obtained the same level of response. The age of the participants was a critical factor issue identified, because it seems that youngest people are more familiar with current technologies and more up to date with current upgrades. As additional information to support the evaluation of IoT Central Hub platform based on response of the participants, a satisfaction survey was requested to be replied after the functionality test and to certify if the application is well acceptance by home users. Basically, they were asked about three simple questions:

- Did IoT Central Hub platform allow good usability?
- Would you install IoT Central Hub platform in your personal mobile?
- Would you recommend IoT Central Hub to a familiar or friend?

To measure respondents' answers, five categories were used. Strongly Disagree, Disagree, Neutral, Agree and Strongly Agree. This classification supports the research be more objective and clearer to the interviewee regarding the evaluation process. At the first analysis of the survey results, it was mostly neutral, but at the second part there was a balance between group of people that disagree and agree. The categories classified to the extremes as strongly disagree and strongly disagree had a few votes in the results, as can be confirmed in **figure 5**.

Regarding the usability issue of IoT Central Hub platform that was not fully accepted by the interviewees. It believes that happen some instabilities in the system and some inconsistencies that impact in the result. But that could be adjusted in a later version if the application were improved.

Regarding the possibility to have IoT Central Hub application installed on the personal smartphone of the participants, it has also not reached a percentage higher than fifty percent of acceptance. Probably, the additional features could be a raison that impact on better acceptance of the users. They have reported that the platform has potential, but extra features could enrich it and it could also make it more attractive. The last question about recommending IoT Central Hub platform to a family member or friend have reached less than fifty percent, was identified referring to the arguments mentioned in the previous paragraphs. Some factors such as instability and addition features were the essential points that they rated the application at the lowest level. However, as already informed, IoT Central Hub platform was praised by respondents as a potential product of great value in the market that can positively contribute to future studies and improvements in future versions of IoT Central Hub application.

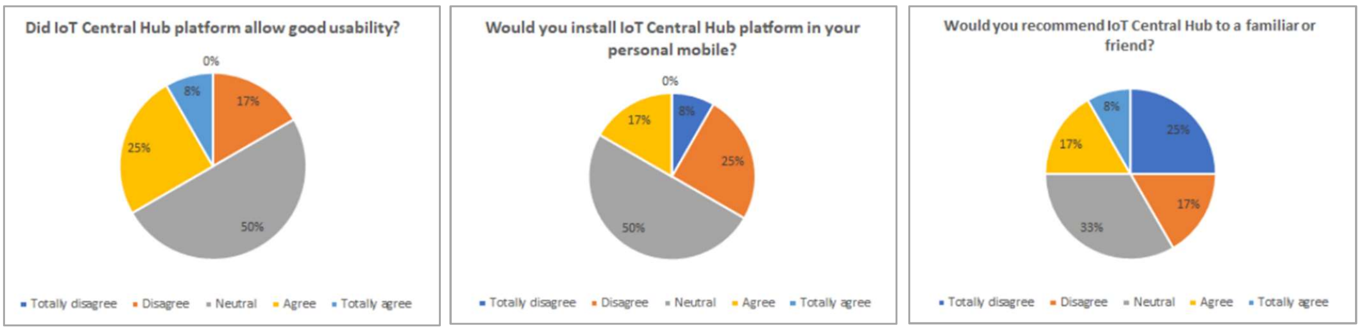

Figure 5. IoT Central Hub functionalities

CONCLUSIONS

Smart devices on the market could create an interaction and dynamism on the information that people receive from the devices. These devices bring many benefits and add value to the people life, as they facilitate the population all daily activity. Based on that, IoT devices have been pleased and popularized among all social groups, as it has been already mentioned throughout during research work. However, IoT devices popularization, it has naturally increased the complexity and significantly numbers of opportunities in market. Therefore, the IoT Central Hub platform solution has brought a great benefit to domestic users who do not have any technical knowledge about this emerging technology. Thus, as shown in the previous chapter, IoT Central Hub platform is partially achieving the goals, as the absence of additional features and a more attractive interface are some of the main points that limited in achieving the goals completely. But even so, IoT Central Hub platform presents a significant feature of controlling local and remote devices in a very intuitive way. Thus, the user has the advantage of using a single platform to manage their IoT devices installed on their smartphone. This research work was able to present IoT Central Hub platform prototype fully usable and testable by user, creating a heterogeneous, scalable, and good usability solution. The platform also allows huge range of expandability of functionality and integration modules to new features to be added. Thus, the developed prototype gives rise to ample study possibilities to future system improvements. Finally, IoT Central Hub platform presented the tests results performed by developer and by users such as good features performance and the usability that it was proposed at the beginning of the research. Thus, we can conclude that the smart device management platform can be installed and implemented to be used by domestic users with less complexity.

Achievements

IoT Central Hub platform has achieved as main objective the remote device data collection and the possibility to be widely exploited to future study to become it a powerful IoT device management tool. Another great achievement of IoT Central Hub application is the complex less configurations, in addition, the system doesn't require to be the technology specialist to use it. Thus, it is possible to have an easy and intuitive tool. In addition to usability, the installation of IoT Central Hub platform is very clear and straight to the point. There are no extra configuration steps and there is no need to configure the device to install, on this way, the user has the comfort of having an application installed without difficulties. In the end, IoT Central Hub prototype was developed to become fully functional and testable. Even with recommendations to the system improvements, users praised the development and the concept of IoT Central Hub platform.

Future Research

IoT Central Hub project was an audacious challenge since the beginning it was intended to carry out the automation functionalities through several technologies and expand it to remote use through the Cloud technology. However, due to the time of research and development of the prototype, in addition to the complexity of the development, IoT Central Hub research allowed a wide range of possibilities to expand the project developed through the following features that were made available for future work. The following features are:

- Adds wireless network access functionality to search and connect devices found in the local network, as well as through developed Bluetooth technology.
- Extends IoT Central Hub prototype functionality through Cloud technology and add functionality for remote device management over the Internet.
- In addition to Cloud functionality, it should be created a service that allows the user to have centralized control through the server, where you can manage client applications by several users.
- Adds user profiles functionality that allows more flexibility to the user through customizable graphical environments and efficient management of most used smart devices.
- Further improve the application's graphical interface so that it can have better usability and can be supported by other types of mobile devices, such as tablets and laptops.
- In addition to improving the graphical interface, it would be very useful for home users to have the reporting functionality regarding the collected data. Thus, it would be possible to create a customizable dashboard with a summary of the main functionalities that they are most relevant and essential for each user.
- Extends system compatibility for platform-appropriate functioning of devices running iOS operating systems in addition to Android on which the prototype was developed.
- Allows the application to have more heterogeneous data collection functionality from smart devices, so that it is possible to perform data processing efficiently.
- Add an artificial intelligence module to the platform, after the implementation of the data collection functionality, so that it can be possible to process the information in an intelligent and productive way for the user.

Finally, the improvements implementations suggested in this chapter will allow the smart device management platform, IoT Central Hub, to become a potential commercial application, so that it would be possible to bring numerous benefits to home users, as already mentioned during this research.

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