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Internet of things (IoT) technologies and tools for the development of prototypes for everyday settings

Tecnologías y herramientas del internet de las cosas (IoT) para el desarrollo de prototipos de entornos cotidianos

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Abstract: This article presents the results of a research project focused on the development of IoT prototypes to solve everyday problems. The project explored various IoT technologies and tools, offering a broad scope applied to different fields. In an increasingly interconnected world, the question arises of how to leverage IoT to improve quality of life. The project's objectives were threefold: to review IoT technologies with the greatest potential, to evaluate the tools and platforms available for developing IoT prototypes in everyday situations, and to build a specific prototype to demonstrate IoT's utility in solving common tasks. The methodology included an exhaustive review of scientific and technical literature, followed by the comparison and selection of IoT tools using established criteria. The prototype construction was carried out using the evolutionary prototyping method. A practical example was the creation of a school bell to optimize adherence to the school schedule, which demonstrated the positive impact of IoT technologies on daily life. In conclusion, IoT offers significant opportunities to address everyday problems and improve people's lives. Understanding IoT technologies and tools is essential to maximize their applicability in daily environments, making these environments smarter, more efficient, and more convenient.

Keywords: Internet of Things, IoT, IoT prototypes, IoT Technologies.

Resumen: Este artículo presenta los resultados de un proyecto de investigación enfocado en el desarrollo de prototipos IoT para resolver problemas cotidianos. El proyecto exploró diversas tecnologías y herramientas IoT, ofreciendo un amplio alcance aplicado a distintos ámbitos. En un mundo cada vez más interconectado, surge la pregunta de cómo aprovechar la IoT para mejorar la calidad de vida. Los objetivos del proyecto fueron tres: revisar las tecnologías IoT con mayor proyección, evaluar las herramientas y plataformas disponibles para el desarrollo de prototipos IoT en situaciones cotidianas, y construir un prototipo específico para demostrar la utilidad de la IoT en la resolución de tareas comunes. La

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metodología incluyó una revisión exhaustiva de la literatura científica y técnica, seguida de la comparación y selección de herramientas IoT utilizando criterios establecidos. La construcción del prototipo se realizó mediante el método de prototipado evolutivo. Un ejemplo práctico fue la creación de una sirena escolar para optimizar el cumplimiento de la jornada escolar, lo cual demostró el impacto positivo de las tecnologías IoT en la vida cotidiana. En conclusión, la IoT ofrece oportunidades significativas para abordar problemas diarios y mejorar la vida de las personas. Comprender las tecnologías y herramientas de IoT es esencial para maximizar su aplicabilidad en entornos cotidianos, haciendo estos entornos más inteligentes, eficientes y convenientes.

Palabras clave: IoT, Internet de las cosas, prototipos IoT, Tecnologías IoT.

1. INTRODUCTION

Since the emergence of electronics as a technology that has enabled the invention and innovation of devices to increase productivity in different socioeconomic fields, the execution of daily tasks to improve people's living conditions. Electronic devices have evolutioned since being devices or machines that allow monitoring, control and automation processes, to become nowdays intelligent devices. For Lopez [1], a smart device must be equipped with sensors that collect data, send it to the internet for analysis and then suggest or execute actions using actuators. and as Evan states [4], at the same time, having the ability to interact with the environment, these capabilities allow us to make decisions and communicate with other objects, systems, and even people and living beings. All this is possible thanks to the technological paradigm of IoT.

The large number of smart devices and machines have caused a growth in internet connections. However, this evolution and advancement has occurred thanks to the fact that the IoT has become a disruptive technology, which has generated significantly positive impacts on various aspects of modern life. The ability to integrate IoT technologies into everyday environments has presented new opportunities to address challenges and optimize tasks that are part of our daily routine. [5].

In this context, this article presents the results of the research project entitled "Technologies and Tools of the Internet of Things (IoT) for the Development of Prototypes of Everyday Environments", which arises from the need to expand the body of knowledge proposed. in the study plan of the Systems Engineering program of the Popular University of Cesar Aguachica Section, which does not include content related to these technologies.

Next, when trying to begin the challenge of building a smart device or developing an IoT system, the difficulty arises in addressing the large number of technologies and tools that exist under this paradigm, by not having a framework of reference and/or a guide. Good practices for building IoT prototypes make the development of the project imperative. The main objective of which is to show the practical application of technologies and tools in the development of IoT prototypes to solve everyday problems, allowing the improvement of everyday and work environments.

To achieve this purpose, it was necessary to begin the task of identifying accessible and promising IoT technologies, and then make a selection based on criteria of usability, costs, availability and their viability to be used in solving everyday problems, for which the application of these technologies and tools was carried out in the construction of a prototype, and thus demonstrate its correct functioning and the usefulness of the IoT in solving daily life problems.

2. METHODOLOGY

Following Hernandez's guidelines [6], it was decided to use a qualitative approach, due to the intention to thoroughly understand the needs and preferences of users in relation to the development of IoT prototypes for the solution of everyday tasks. This approach allowed for a comprehensive evaluation of IoT technologies and tools, as well as their understanding.

Because it is an applied type of research, and to fulfill one of the specific objectives formulated, the rapid prototyping method was implemented in the experimental design, as stated by Del Giorgio Solfa and Lara Marozzi. [7],"The speed in prototyping allows designs to be adjusted in an agile manner, optimizing the development process," this method facilitated the iterative and flexible development of the IoT prototype.

Following this design, initial versions of the prototypes were built based on the technologies identified in the first specific objective, which was improved and refined in successive iterations based on the findings obtained in the evaluation of tools and platforms carried out in the second objective. specific.

According to Alapizco Bobardel & Vázquez Rodríguez [8], andThe Rapid Prototyping method is a product development approach that allows the rapid creation of initial models to evaluate concepts and functionalities with the active and permanent participation of the client, which are key to effective innovation. The same way, states that the use of this method allows ideas to be quickly validated and development time reduced. Zumba Gamboa and León Arreaga [9], they propose, Since this concept of rapid prototyping has been developed and popularized by several experts in software engineering and product design, it can be adapted according to the needs of each researcher. For the present case, the following phases were defined:

Phases 1. Definition of the problem and prototype requirements
Phase 2. Conceptual design
Phase 3. Rapid prototype construction
Phase 4. Initial evaluation and testing
Phase 5. Iteration and optimization
Phase 6. Documentation

Data collection was carried out through several procedures, including open and semi-structured interviews (user stories), observations and operational tests in real environments, which allowed the collection of detailed information on the needs and preferences of end users in relation to with the daily tasks that were sought to improve. Furthermore, following what was expressed by Tamayo [10],Direct observations were made in everyday and work environments to better understand the specific challenges and problems that users face in their daily lives.

3. RESULTS

The identification of consolidated IoT Technologies, within the framework of the first Specific objective, was carried out through a systematic search of literature in academic databases such as Google Academic, ScienceDirect, Dialnet, SCielo, repositories of degree works from various universities, Likewise, technical reports and documentation from Manufacturers were reviewed. To organize and classify the results, the structure shown in Figure 1 of the components of an IoT system based and adjusted to the proposal by Romo Gonzalez & Villalobo Alonso was proposed. [11], suggestions were also consideredby Navarro Pino, Arango Trillos, Rincón Pinzón, and Ramirez Orellano [12],

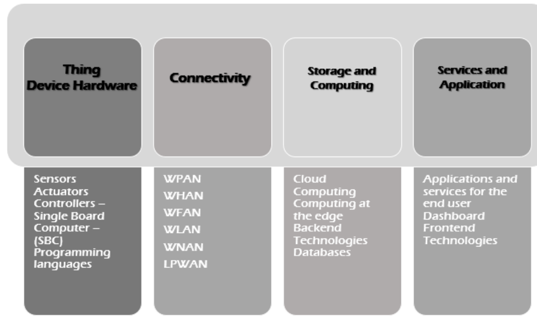

Fig 1. *Components of an IoT system*
Source: *author's own creation*

Next, the evaluation of technologies and tools was carried out with the purpose of recommending and selecting through the construction of the test prototype used to validate its viability, for which criteria such as usability, cost, learning curve, accessibility and the ability to solve everyday problems.

to start the design process before building any product (in this case a smart device), as good practice always various experts such as Gámez López and Sánchez [13], recommend having a framework of reference in this context to define the architecture to use. Although Sethi and Sarangi [14],They highlight that there is no consensus on the architectural model to use, however, a review and selection was carried out based on the number of layers 3, 4, 5, 6 and up to 7, including El Hakim's proposal. [15].Furthermore, the scope of its application was taken into account; health sector, transportation, agriculture, education among others. Finally, it was decided to use and recommend the 4-layer model proposed by Boujrad, Lazaar, and Hassine. [16], which uses Wireless Body Area Network (WBAN) technology and presents similarities with the Ortiz architecture [17].

One of the reasons why the 4-layer architecture was selected is that it presents a lot of relationship and is consistent with the division structure of the components into which we can divide an IoT system. However, for the development of IoT prototypes in other areas, it is proposed to review the results presented by Buitrón Ruiz [18].

As can be seen, the components of the perception layer are related to the components for the construction of the physical object, which include sensors, actuators, development boards, the programming languages to program the boards, including the energy systems.

As technologies and tools of the perception layer, the following were reviewed: SBCs such as Raspberry pi, Arduino, Node-MCU, Dev-Kit, generic boards based on SOC ESP8266 and ESP32, the programming languages of these boards such as the one used by the IDE of Arduino based on the high-level Processing language, which is very similar to C++, and the Arduino IDE is compatible and supports many of the aforementioned boards. Another programming language relevant to this area is Python.

In relation to the components necessary to establish connectivity to the Internet and other nearby devices, wireless personal area network technologies, wireless local area networks, wide area and low power wireless networks, among others, were reviewed. Although only wireless technologies have been mentioned as an example, it does not mean that wired technologies are excluded from the IoT. The existing wireless standards on the market are abundant, although they are aimed at users with specific needs, and they are selected based on criteria such as coverage, range, transfer rate or bandwidth, energy consumption, frequency band, cost and availability embedded in SBC, among which the Wi-Fi standards (802.11n/ac/ax/ad), Bluetooth and other 802.15 standards such as ZiBee, LoRaWAN, Sigfox, 4G, LTE, 5G, among others, are identified in the review [19].

Among the components for data storage and processing, the most common thing is that this is done in the cloud, whether public or private. Here technologies such as cloud computing and Edge computing become relevant. The latter has become a trend within the IoT by allowing the data load sent to the Internet to be minimized and in this way optimizing cloud processing and the transfer rate, which allows lowering economic costs when contracting on-demand services, by while generating benefits to the environment [20].

Among the technologies and tools identified to be used as a storage and processing component, framed in the intermediate layer, the following were reviewed: Mosquitto as an MQTT broker, Firebase, Arduino IoT Cloud, MyQttHub, Google cloud, Amazon Web Services, including programming languages for the Backend development.

Finally, the technologies and tools with which the applications are developed were reviewed so that the system interacts with the end user, although sometimes there are M2M prototypes that do not require interaction with a human for decision making. Here programming languages, framework for frontend development and dashboard were identified, among which are: Java, NodeJS, ThingsBoard, NodeRed, Arduino IoT Cloud.

To summarize the results of the evaluation and selection of the tools to be used, Figure 2 shows the final scheme of the IoT prototype to automate the operation of a school siren used to validate the results.

Specific Objective 3 was achieved by successfully building an IoT prototype using the technologies and tools identified in the previous objectives. The developed prototype demonstrated the feasibility and usefulness of the IoT in daily life by addressing specific challenges in everyday and work environments, Table 1 shows the functional requirements defined for the prototype.

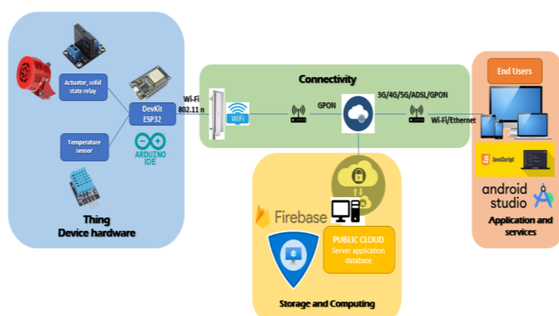

__Fig 2.__ Components of the School Siren IoT prototype
__Source:__ author's own creation

Table 1: *Prototype functional requirements*

code	Description of the requirement
RQ1	The device must control the sound of the siren at each class change
RQ2	The device must have a button to select pre-configured schedules
RQ2	The device works on a default schedule
RQ2	The device must have a button to update the date and time from the internet
RQ2	The device must detect weekend days, Saturdays and Sundays and not activate the siren
RQ2	Modify the schedule in standalone mode via Bluetooth

RQ2	The device must have a screen that displays (Tablet): Date and time, Current class interval, selected settings
RQ2	The device must have silent operation
RQ2	Device must be manually activated
RQ2	Android application, should show: active time of day, time interval, schedule schedules (Coordinator role), Receive notifications, Send notifications (Coordinator role), Allow activating siren (Coordinator role), Silent mode (Coordinator role)

Source: *author's own creation*

Once the requirements have been analyzed and the conceptual designs have been prepared, we proceed to the construction of the electronic circuit of the physical object, which can be detailed in the diagram of thefigure 3,The use of the selected technologies in the previous objectives can be evidenced, Figure 4 shows the real prototype.

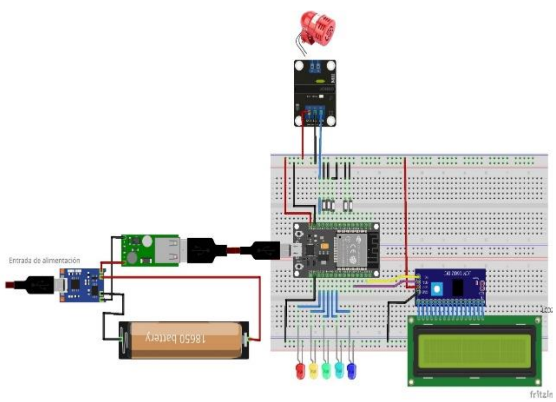

Fig 3. *Connection diagram of the electronic circuit.*
Source: *author's own creation*
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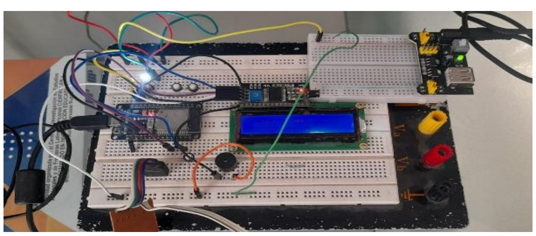

Fig 4. *Real test prototype.*
Source: *author's own creation*

Likewise, Figure 5 shows the end-user application, with which the physical device is interacted with. At the same time, Figures 6 and 7 show a portion of the developed code and the database used to store the data respectively.

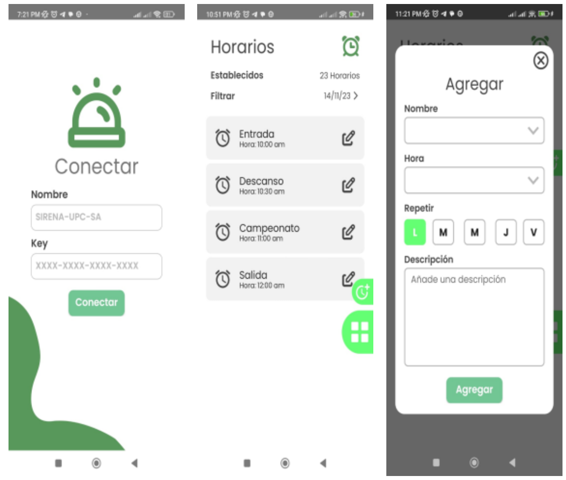

Fig 5. *APP for Smartphone with Android OS.*
Source: *author's own creation*


```
#include <ArduinoJson.h>
#include <ArduinoJson.hpp>
#include <ESP32Time.h>
#include <Arduino.h>
#include <WiFi.h>
#include <FirebaseESP32.h>
#include <addons/TokenHelper.h>
#include <addons/RTDBHelper.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

// Dirección I2C de la pantalla LCD1602A (puede variar)
#define LCD_ADDR 0x27

// Define las dimensiones de la pantalla LCD1602A
#define LCD_COLS 16
#define LCD_ROWS 2

// Crea un objeto de la clase LiquidCrystal_I2C
LiquidCrystal_I2C lcd(LCD_ADDR, LCD_COLS, LCD_ROWS);

#define WIFI_SSID "SIRENA-ITI"
#define WIFI_PASSWORD "SIRENAIOT2024"

#define API_KEY "AIzaSyAQCW-bNwy5RmZOlB5W8EHwWiOwrlA_OEE"
#define DATABASE_URL "esp32-ab14f-default-rtdb.firebaseio.com"
#define USER_EMAIL "control_sirena@gmail.com"
#define USER_PASSWORD "12345678abc"

FirebaseData fbdo;
FirebaseAuth auth;
FirebaseConfig config;
```

Fig 6. *DevKit-1 board code.*
Source: *author's own creation*

The results obtained highlight the importance of the careful selection of technologies and tools for the development of IoT prototypes, as well as their impact on the solution of everyday tasks. These findings support the idea that IoT has the potential to significantly improve quality of life and efficiency in everyday environments.

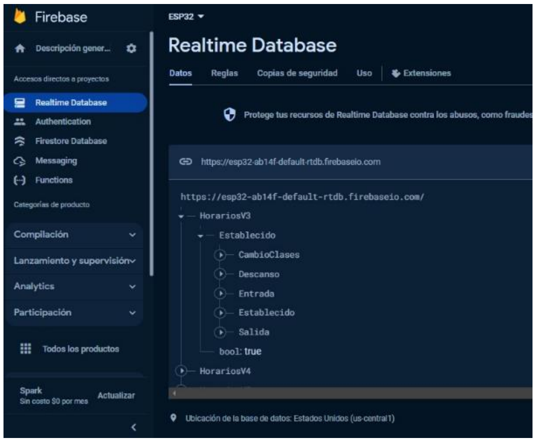

Fig 7. *Database in Firebase*
Source: *author's own creation*

4. RECOGNITION

Highlight the financial and logistical support provided by the Popular University of Cesar Aguachica Section for the development of this research work, which through its strategy of financing projects for research groups and seedbeds make research training and scientific research possible.

5. CONCLUSIONS

Conclusively, the study carried out allows us to affirm that the application of technologies and tools of the Internet of Things (IoT) in the development of prototypes for the solution of everyday tasks can be used as a promising strategy to improve efficiency and comfort in environments. domestic and even work.

The successful construction of the IoT prototype and its subsequent implementation in everyday environments have revealed the transformative potential of the IoT to improve quality of life and efficiency in performing common tasks. Process automation, M2M iteration, machines with people, the environment and living beings, the ability to monitor and make decisions or execute actions autonomously in real time, have proven to be valuable tools to optimize operation and management. of resources in everyday environments. In addition, generating positive effects on the environment, optimizing energy and economic resources.

Another important finding to highlight within the connectivity component technologies is the relevance and positioning of technologies such as Bluetooth Smart Ready for its low energy consumption (BLE) and Wi-Fi, which are crucial for the development of IoT prototypes. in everyday environments. These technologies allow efficient and reliable connectivity between devices, making the construction of smart devices easier and faster. Taking into account the above, as future research studies, it is advisable to delve into the development of IoT Prototypes with Energy Efficiency criteria.

Likewise, the evaluation of open source tools and platforms such as Arduino made it possible to establish their importance in the development of accessible and adaptable IoT solutions. These platforms offer flexibility and functionality, helping Makers deploy effective, customized IoT prototypes to address a variety of everyday tasks.

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