Monitoring System for Smart Buildings - Apolo Building Case

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Abstract. The demand for better safety and comfort conditions in social centers served as an incentive to improve the automation of buildings, making them intelligent systems that could be integrated. However, alongside these innovations, there has also arisen a concern for the ecological risks surrounding the smart building. With these factors as a basis, this work aimed to monitor three main systems within each apartment in the Apolo Building (Bragança, Portugal), namely electricity consumption, water consumption, and waste disposal. These systems are integrated through a common database, where they are being stored. This study intends to create a platform for data analysis, making it accessible to the consumer, raising awareness of the expenses generated, and looking for short and long term efficiency measures.

Keywords: Internet of Things · Smart Buildings · WSN.

1 Introduction

Buildings were created to become the center of social spaces, for either economic or residential activities. With the advancement of life in society within these spaces, comfort and safety began to be prioritized [15].

In the 1960s, the first centralized control equipment appeared, which were used for air conditioning of the environments. In the 1970s, with the advance of microcontroller use, there was an expansion in the control processes, followed, in the 1980s by the advance in the need to improve the workplace's, telecommunications services and computer systems. These requirements would contribute to the emergence of three pillars of the intelligent building system: automation, telecommunications and computer systems [15].

However, there was great confusion in the use of the term *smart*, because it induced people to have unrealistic expectations about constructions. Due to the lack of economic capacity and poor familiarity of new technologies, these expectations have been frustrated, in a way, the therm gained a negative connotation [15].

In order to centralize and promote smart buildings, the Intelligent Building Institute (IBI) Organization defined an intelligent building by [20]:

> A building that provides a productive and cost-effective environment through optimization of its four basic elements - structure, systems, services and management - and the interrelationship between them. Intelligent buildings help bussiness owners, property managers and occupants to realize their goals in the areas of cost, comfort, convenience, safety, long-term flevibility and marketability.

Therefore, it was concluded that an intelligent building would not only be automated, but that it provides greater integration between the systems [11], being these related to infrastructure, automation of systems and control of them, management and maintenance.

Following the structuring of an intelligent building, integrating the systems highlighted here, the present work aims to collect, store and analyze the data of the Apolo Building, using as database the platform InfluxDB and the web application Grafana for better visualization of the data.

The rest of the paper is organized as follows: Section 2 presents related work, followed by Section 3 which presents the architecture of the developed system. Section 4 presents the developed work and its validation, with the results and future work presented in Section 5.

2 Related Work

Wireless Sensor Networks (WSN) is an infrastructure that contains sensing, computing and communication elements interconnected by a single network node that allows the measurement, collection and control of the systems involved [2]. According to [13], the WSN consists of two important parts, namely hardware and software. For the first, a typical sensor node is composed of a low-power embedded processor, memory, sensor with ADC units, radio transceiver, location finding system and power supply. The software is composed of operation system microcode, sensor drivers, communication processors, communication drivers and data-processing mini-applications. In [7], an energy management solution using WSN and web services with middleware technology. A web application developed in the project was used to illustrate the concept of monitoring the data collected by sensors, allowing on/off control of electrical applications. In [16], a software solution is presented to bridge the gap between raw hardware capability and a viable software system. The TinyOS application has a small physical size, developed "to support the concurrency intensive operations required by networked sensors with minimal hardware requirements".

Energy and water efficiency are major concerns in the construction of a smart building [12]. This concern must go from the project stage through construction and must be maintained during the use of the building. According to the Official Journal of the European Union [19], buildings had an aggregate of 40% of the total electricity consumption of the European Union, with consumption increasing each year. In order to this, the Directive 31/2010/UE[4] promoted energy efficiency measures by stimulating automation of buildings and monitoring of technical systems as an effective alternative. In this way, consumers gain access to information about their consumption, bringing more awareness about their behavior. In order to optimize the monitoring processes of constructed buildings, measurement can be done through passive Hall Effect sensors, which are able to measure the voltage or electric current in the wiring of the building through a clamp-shaped sensor.

[4] Directive 2010/31/UE of the European Parliament and of the Council of 19 May 2010 as amended by Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 and Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018.

With regard to water consumption, World Water Development Report [4] states that the immediate concern is not only with the availability of water, but also how it has been managed. Focused on efficiency measures, Teixeira [18] developed a system that allows certification and labeling of water efficiency. According to the study in his project, the building where the measures were applied there was a reduction of 63.9% of the water consumption.

Another important system considered in this work is the waste management system, which has evolved in the development of smart cities through Internet of Things (IoT). In [3], Cerchessi et al. developed a waste management optimization application by monitoring the capacity of waste bins. Through the use of *LoRaWAN* [17], measurement is done by ultrasonic sensors docked in the recycle bin. The data is collected and analyzed in real time, allowing for planning of the next waste collection. With this technique, an 18% reduction in collection time and a long-term optimization of waste policies was observed.

All this integration between objects and systems is possible through *Internet of Things*. The term, which originated the origin in 1999 with the researcher Kevin Ashton [1], was associated with the technology that integrated inanimate objects, allowing communication, transmission and executions of various functions. However, the fast evolution of technologies involved brought significant concern to the industry. In [10], highlights that the growing evolution and increasing complexity of IoT brings troubling issues involving equipment heterogeneity, exorbitant amount of data, security and privacy.

3 System Description

The data was collected by three main sensors, these being the YF-B2 sensor, for measuring water flow, the weight cell, for measuring of waste disposal, and finally, the IoTaWatt, for monitoring electricity consumption. The first two have a connection with an ESP32 microcontroller, which sends the data to the database via WiFi. The IoTaWatt, however, sends directly via WiFi to the InfluxDB database. The constructed of architecture can be visualized by the diagram in Fig. 1.

For comparison and better analysis purposes, the DHT11 sensor, responsible for measuring the local temperature and humidity, was also added to the system. The sensors DHT11, the weight cell, and the water flow are designed to communicate with the ESP32, which is responsible for collecting and sending the data.

The IoTaWatt [8] is a device with an integrated microcontroller capable of measuring up to 14 different circuits through the passive sensor. A wall transformer converts the local voltage to a reference voltage, allowing the unit to determine the voltage and frequency of the monitoring line. It has its own web application so that real-time monitoring can be done. Despite this ability, we configure the device to transmit the data to the database via WiFi.

The choice of microcontroller ESP32-WROOM-32D [6] was by the fact that it is an embedded system board that integrates WiFi and Bluetooth on the same board, with low power consumption and high performance.

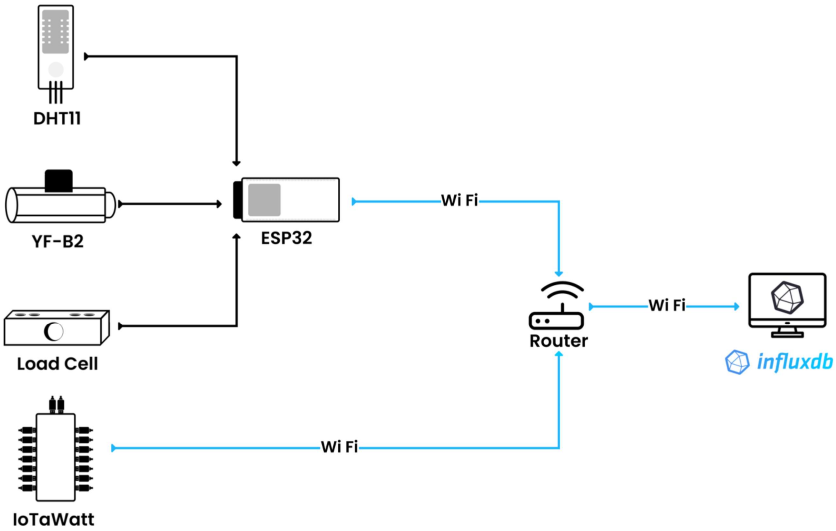

Fig. 1: System Architecture

The database chosen was InfluxDB [5], a platform developed by InfluxData that has a great popularity in systems involving Time Series Database (TSDB) [14]. This platform uses a language similar to Structured Query Language (SQL), with a high performance for times series. For a better view of the stored data, Grafana [9], a web application that allows the creation of monitoring panels by combining the data obtained in InfluxDB, will be used. The entire system was installed directly on the Windows operating system on the local computer of the building management.

4 Work Development

As mentioned, the measuring systems were developed to monitor the apartments in the Apolo Building. As the building is in the final phase of construction and with much of the structure already finished, an attempt was made to interfere as little as possible on the construction process.

The tests are being carried out in just one pilot apartment, where the IoTaWatt sensor, balance sensor and temperature and humidity sensor are already located. The water flow sensor depends on the installation of a professional, because it is the only one that makes necessary intervention in the structure of the building, it has not yet been possible to integrate it in the data collection. With this exception, it is possible to observe already in Fig. 2 the data being collected in the apartment, through the monitoring page created in Grafana.

For the waste weighing system, a 3D-printed prototype was developed that allows any waste drum to be used in the system. A button was attached to allow changes to the drum.

As the hardware part is still under development, it will not be presented at this time.

Fig. 2: Grafana Monitorization

5 Conclusions and Future Work

The integration of systems has become an important source of centralisation of information for the entire process developed in the building. Projects like this have great potential to have many doors open for future applications. As noted, using low-cost sensors and an open source database it is possible to create an integration with several input possibilities. This paper presented a monitoring proposal for buildings, so that, with the integration between systems, a diagnostic analysis of the data on consumption can be made.

The installation already allowed an advance in data acquisition and storage, so that, although it is not a real consumption, since the apartment does not have a resident, it allows us to develop and validate the proposed system. As the amount of collected data is still fairly small and the installation in all apartments is pending, we present the current results only to demonstrate the operation of the designed system. The objective of the work presented here is, through the data collected under the authorization of the resident, and the application of machine learning, to present possible exaggerated or peak-time expenses that could be avoided. The application of a linear regression will allow the identification of these expenses and predict the resident's consumption behavior, offering ecological solutions that allow economic and resource spending reduction. It is worth pointing out that the objective is not to act directly on the resident's behavior, but the data analytics allows to observe the behavior through the information presented to them. It is also expected that the data presented in Grafana will be better structured in order to make the application more objective. In the future, an application is also expected to be developed for the residents of the building, so that they might be aware of the building's consumption of resources.

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