Environmental Quality Supervision for Enhanced Living Environments and Laboratory Activity Support using IBM Watson Internet of Things Platform

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Abstract. Temperature and humidity are extremely important not only for occupational health and well-being but also for supervising laboratory activities. Laboratories are places characterised by several contamination sources which lead to significant poor indoor quality conditions. Laboratory activities require real-time monitoring supervision. Around 40% of the energy consumed worldwide and around 30% of the carbon dioxide liberated are related to indoor living environments. Further, a substantial amount of this energy is used to provide a satisfactory human perception of the thermal conditions. The IBM Watson IoT Platform provides data integration, security methods, data collection, visualisation, analytics, device management functionalities and allows data to be sent securely to the cloud using MQTT messaging protocol. This document presents a temperature and humidity real-time supervision system based on Internet of Things architecture named ***iTemp+***. The system incorporates physical prototype for data acquisition and uses IBM Watson IoT for data storing and consulting. The IBM Watson IoT Platform provides data integration, security methods, data collection, visualisation, analytics, device management, artificial intelligence and blockchain functionalities which are not implemented in the concurrent IoT platforms. The results obtained reveal that IBM Watson IoT platform offers several enhanced features for device management and analytics and can be used as a powerful approach to provide IEQ supervision.

Keywords: Ambient Assisted Living, Enhanced Living Environments, IBM Watson IoT, IEQ (Indoor Environment Quality), IoT (Internet of Things), Laboratory Environment Conditions

1 Introduction

Indoor living environments include several types of spaces, workplaces such as offices, hospitals, public service centres, schools, libraries, leisure spaces and also the cabins of vehicles [1]. In particular, schools are an important place to monitor. Typically, a large number of occupants, the time spent indoors, and the higher density

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of occupants justify the need to develop automatic supervision systems to provide a healthful and productive workplace for the students, teachers and the school staff [2].

In most higher education establishments in Portugal, laboratories are also used as classrooms and should also be monitored. However, monitoring must ensure different conditions throughout laboratory and teaching activities with reliable data quality. The satisfaction of the indoor thermal conditions is of utmost importance for the occupants, particularly when compared with sound, light and air quality conditions [3]. Typically, the occupants are satisfied with temperature ranges of 17-30 ºC. Furthermore, the indoor temperature conditions are affected by several factors. These factors can be classified as physical factors such as humidity, radiant temperature, air temperature and air velocity; and as personal factors such as clothing insulation and metabolic heat [4]. Although, for laboratory experiments, the recommendation is 23 ºC (±5 ºC) for temperature and <70 % for relative humidity. A study on the thermal comfort in a Portuguese school is presented by [5].

Around 40% of the energy consumed worldwide and around 30% of the carbon dioxide liberated are related to indoor living environments. Further, a substantial amount of this energy is used to provide a satisfactory human perception of the thermal conditions. Thermal comfort is a multifaceted subject related with a lot of interconnected parts which are not easy to measure and study. However, the introduction of personalised conditioning techniques is probably the best way to rise the individual thermal comfort acceptance [6].

Indoor environment quality (IEQ) is based on random sampling. Nevertheless, these methods only offer data related to a particular sample and don't provide any details of spatio-temporal changes which are specifically significant in laboratory activities. The IEQ supervision system improves the detection and correction of unhealthy conditions. However, there is a lack of consensus on measuring protocols. Therefore, the same building could have different evaluations which avoid benchmarking [7].

Laboratory ventilation aims to protect the occupants from possible experience to dangerous materials and to offer comfort in an energy efficient manner. Therefore, it is significant to have automatic devices in order to detect any variations during laboratory activity [8]. The indoor microbial levels are influenced by several parameters such as ventilation, temperature, relative humidity and occupants number [9].

IBM Watson IoT Platform is a foundational cloud that offers device connecting and consulting feature as long with an extensive set of built-in and add-on tools for the Internet of Things (IoT) architectures [10]. The IoT concept must be assumed as the ubiquitous presence of physical objects which incorporate sensing capabilities and can cooperate in order to achieve a predefined goal [11], [12]. IoT architectures will bring several effects on actual world and society. The IoT applications continue to enhance several activities of day to day life. IoT has been used as a foundational base to develop several types of applications in numerous contexts such as smart homes and smart cities. Particularly, IoT has been used for ambient assisted living and e-health to create

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automatic and intelligent solutions which can provide new data and computational methods for enhanced living and occupational health [13].

This document presents an IoT solution for indoor temperature and humidity real-time supervision named ***iTemp***+. The system incorporates a hardware prototype for environment data acquisition and use IBM Watson IoT for data storage and consulting (**Fig. 1**).

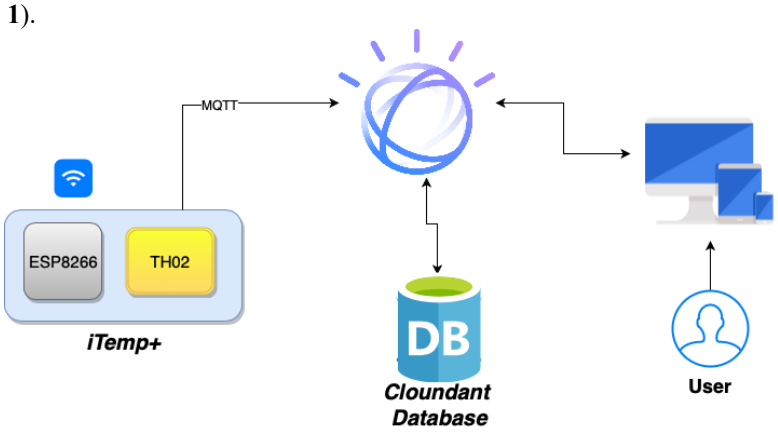

Fig. 1. ***iTemp***+ architecture.

The ***iTemp***+ is a totally wireless system which has been developed using open-source technologies. This system has numerous advantages when compared to existing competing systems. The ***iTemp***+ is a cost-effective solution which incorporates a modular and scalable architecture which lead to an easy installation process. The ***iTemp***+ use the ESP8266 as microcontroller unit which support built-in Wi-Fi compatibility.

The rest of this document is organized as follows: Section 2 describes the related work and Section 3 is presents the system architecture of the ***iTemp***+ solution; Section 4 provides the discussion and results, and Section 5 concludes the document.

2 Related Work

Numerous systems on indoor quality supervision can be found in the literature. This section presents several IEQ systems that incorporate open-source, and cost-effective technologies are described.

A cost-effective Wireless sensor network (WSN) solution for precision agriculture implemented in a pepper greenhouse which incorporates proper assessment methods for irrigation and facilities monitoring and remote control is being proposed by Reference [14].

A WSN for temperature distribution supervision system in large-scale indoor space is proposed by Reference [15]. This system objective is to increase measurement quality wirelessly transmitted, recognize temperature distribution patterns, and improve

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the distribution of supply air rated flow rate to multiple supply air terminals which are controlled to provide specific temperature conditions.

An IoT solution to control temperature and fire supervision which incorporates Message Queue Telemetry Transportation (MQTT) broker on Amazon Web Services was proposed by Reference [16].

An Android smartphone application named Orvalho was been developed to evaluate the thermal comfort indicators of animals and individuals by physically inserting meteorological data or by acquiring data from mobile devices using Bluetooth [17].

Various indoor supervision open-source solutions based on IoT which offer data acquisition, processing and transmission features from different locations at the same time and real-time data consulting through Web and mobile applications in proposed by the authors of [18]–[27].

The ***iTemp+*** is an automatic temperature and humidity monitoring solution for indoor environments, particularly for the supervision of laboratory activities. Is an entirely wireless solution built on the base of the ESP8266. The IBM Watson IoT platform offer efficient services for device connection using MQTT [28]. In the developed solution, the Watson IoT platform acts as the MQTT broker and is thus responsible for distributing messages to connected ***iTemp+*** prototype (**Fig. 2**). The data is stored in a Cloudant DB, a scalable JSON document database for the Web, mobile, IoT and serverless applications.

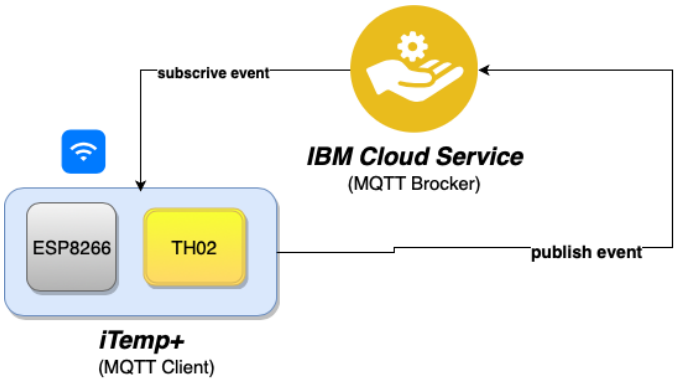

Fig. 2. ***iTemp+*** and IBM Cloud service integration.

3 Materials and Methods

The ***iTemp+*** was developed to be a cost-effective solution that can be easily connected to Wi-Fi and installed by the final user to avoid installation costs if done by certified professionals. It also avoids privacy issues that come with the home installation. In this section, the hardware and software technical data used in the development of the proposed solution will be discussed in detail.

The temperature and relative humidity sensor used is a cost-effective TH02 sensor (*Grove*). This sensor has reliable data acquisition properties, and the measurement

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range is 0-70 ºC and 0-80% for temperature and relative humidity, respectively. This sensor is was selected taking into account the cost-effective approach of the solution but also because the measurement range covers the majority of the scenarios.

The ***iTemp***+ incorporate a D1 Mini ESP8266 (*Wemos*) module as microcontroller and the temperature and humidity sensor module used is connect via I2C interface. The ***iTemp***+ hardware is showed in **Fig. 3**.

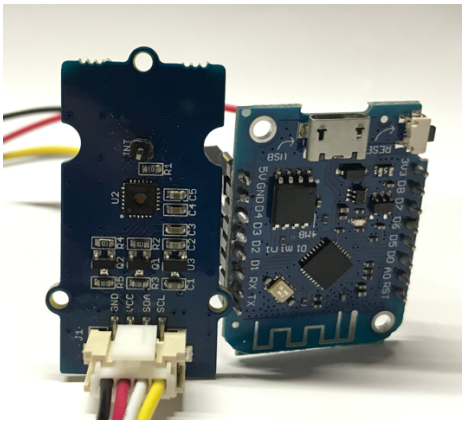

Fig. 3. ***iTemp***+ prototype.

A brief description of the components used in the development of the ***iTemp***+ is presented in **Table 1**:

Table 1. Components data.

Component	Description
Wemos D1 mini	Miniaturized Wi-Fi module with 4MB flash based on ESP-8266 11 digital pins (all support I2C, PWM and interrupt except D0) 1 analog input (3.2 max voltage) Operating voltage: 3.3V Clock speed: 80MHz/160MHz Dimensions and height: 34.2mm x 25.6mm and 3g
Grove I2C TH02	Temperature and humidity sensor Range: 0% ~ 80% RH; 0 ~ 70 °C Accuracy: ±4.5% RH; ±0.5°C Operating voltage: 3.3V ~ 5V

The ***iTemp***+ provides an easy Wi-Fi configuration. The ***iTemp***+ is by default a Wi-Fi client, but if it is unable to connect to any previous configurated Wi-Fi network a hotspot will be created with an SSID “iTemp+”. The end-user can access this hotspot to configure the Wi-Fi network to which the ***iTemp***+ is going to connected. **Fig. 4** represents the Wi-Fi network configuration process.

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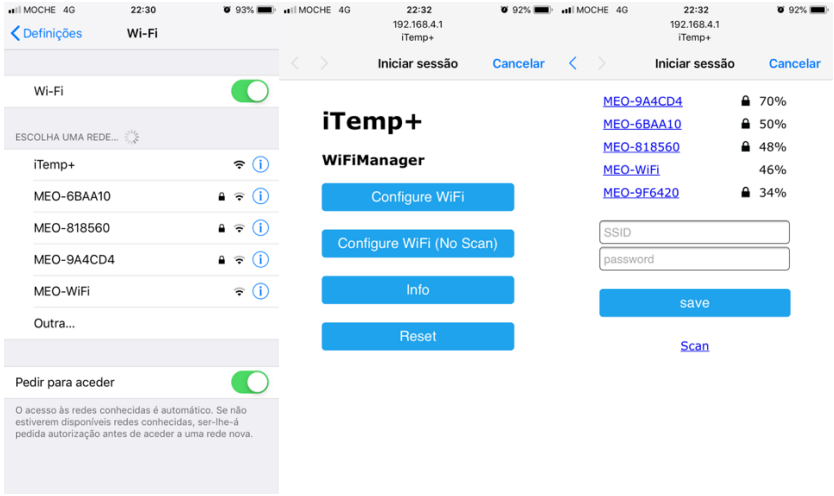

Fig. 4. ***iTemp***+ easy installation process.

4 Discussion and Results

The system test has been conducted inside a laboratory located in a Portuguese university using one ***iTemp***+ station. The monitored laboratory is naturally ventilated by manually open of windows or doors and doesn't have dedicated ventilation slots. The temperature and humidity have been supervised on the context of thermography experiments to test the supervisory solution in the course of laboratory activities but also in real-time environmental supervision of teaching activities for enhanced living environments and well-being (**Fig. 5**).

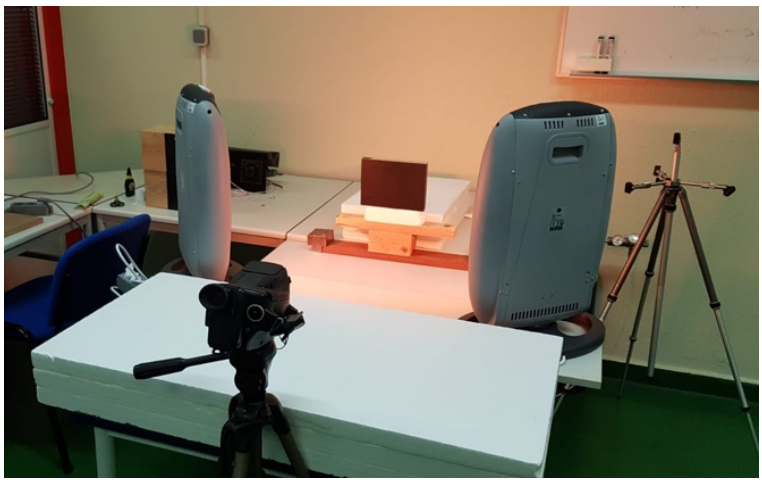

Fig. 5. Thermography experiments supported by the ***iTemp***+ prototype.

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The tests performed indicates the ***iTemp+*** ability to provide real-time supervision not only for laboratory experiments but also for enhanced living environments and occupational health using IBM Watson IoT platform. The collected data can be stored for further analysis and correlation among laboratory experiments to study the effect of the indoor conditions on the tests conducted. This IoT platform allows the user to consult the collected data history through a browser-compatible device. **Fig. 6** and **Fig. 7** represent temperature (ºC), and relative humidity (%) data collected respectively.

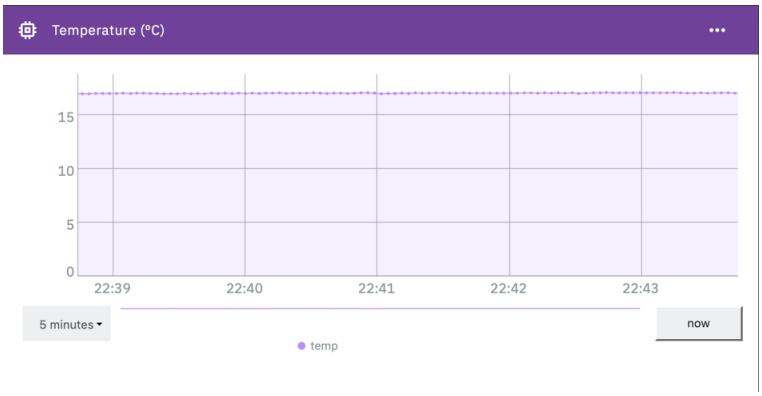

Fig. 6. Temperature monitoring data (ºC) collected in the tests performed.

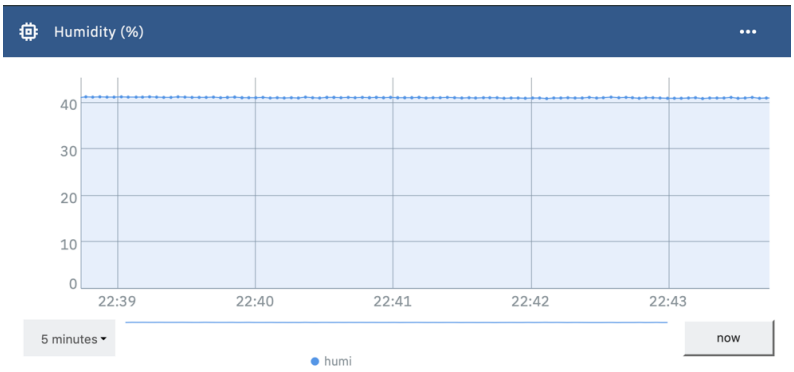

Fig. 7. Relative humidity monitoring data (%) collected in the tests performed.

The IBM Watson also allows the user to create a custom dashboard for a detailed examination of the complete temporal variation. Consequently, the ***iTemp+*** solution is a significant method for temperature and humidity data assessment for environmental monitoring. The proposed solution incorporates several advantages when compared with the majority of the competing systems such as miniaturized size, scalability, and modularity with lead to an easy installation.

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The IBM Watson IoT offers an integrated solution for device management and analysis. Using this platform, the developer can easily configure and manage his devices and as well as consult the state of the device. Additionally, he can access a full detailed log of the device activity (**Fig. 8**).

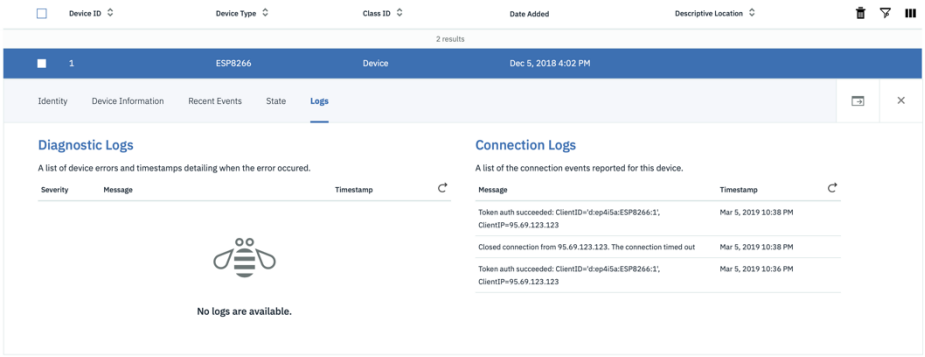

Fig. 8. IBM Watson IoT device management

The IBM Watson IoT incorporates another significant advantage for IoT architectures; using this platform is possible to access a full detailed network usage of the IoT devices. A custom dashboard for device management created by the authors is shown in **Fig. 9**.

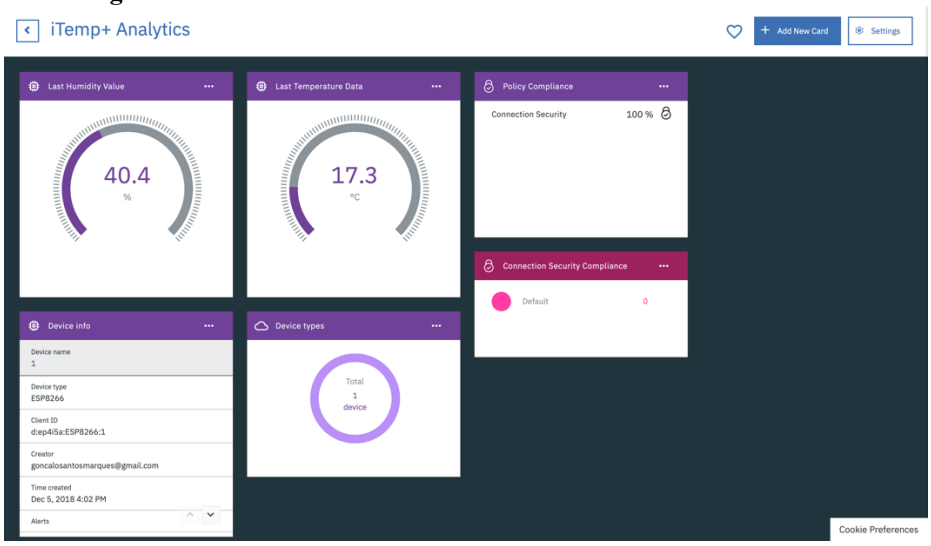

Fig. 9. IBM Watson IoT network usage management dashboard

The IBM Watson IoT Platform provides data integration, security methods, data collection, visualisation, analytics and device management functionalities which are not implemented in the concurrent IoT platforms (**Table 2**). Moreover, the IBM Watson IoT Platform provides artificial intelligence and blockchain integration.

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Table 2. Summary of similar IoT platforms.

IoT Platform	Integration	Security	Data collection	Visualization	Analytics	Device Management
IBM Watson	REST API	√	HTTPS, MQTT	√	√	√
Ericsson Platform	REST API	√	CoAP	×	×	√
Xively	REST API	×	HTTP, HTTPS, Sockets, MQTT	√	×	√
ParStream	R, UDX API	×	MQTT	√	√	×

People's considerations of temperature conditions are supported by their habits and behaviour. On the one hand, prolonged exposure to the high temperature levels increase the occupants' temperature requirements and turn the difficulty to get a comfortable exposure to environments with neutral temperatures. On the other hand, uncomfortable thermals experiences can bring the lead to an easier thermal adaptation [30].

A personal comfort model is a novel methodology for thermal comfort. That methodology calculates people thermal comfort behaviour, instead of considering a standard value extracted from a large population. IoT and artificial intelligence algorithms can “learn” the occupant thermal comfort by analysing data collected from the environment where the person is [31]. The IBM Watson IoT platform offers tools not only to create machine learning and identification of patterns but also to supervisor and enhance diverse machine learning and deep learning models by performing automatic tests and matching results. Therefore, this platform can be assumed as a unique platform to develop new and personal IEQ supervision systems.

Furthermore, the IBM Watson IoT platform’s built-in blockchain allows users to add selected IoT data to private blockchain ledgers that can be included in shared transactions for enhanced IoT security applications [32]. The IBM Watson IoT platform can be assumed as one of the most powerful artificial intelligence systems and is already used in the healthcare field to support medical diagnostics [33].

As future work, the principal objective will be to perform technical enhancements including the devolvement of a mobile and smartphone application, using the IBM Cloud services to provide the configuration of setpoints to notify the user when the IEQ is poor.

5 Conclusions

This document had proposed an IoT solution for indoor temperature and humidity real-time supervision named ***iTemp+***. IEQ is affected by several factors such as noise, light, air and temperature conditions. Poor IEQ significantly affects well-being and occupational health, especially of children and older adults who are most fragile.

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Technological enhancements and the increase of low-cost controller and sensors lead to the proliferation of IoT systems which incorporate the important potential for the development of smart solutions for smart cities in general and indoor monitoring in particular. Real-time monitoring systems turn possible not only to quantity the IEQ index in distinctive locations but also to offer reliable information to identify insalubrious conditions automatically.

The ***iTemp+*** has several advantages when compared to the majority of existing solutions. The proposed solution is scalable and modular which lead to an easy installation. Further, the ***iTemp+*** offer accurate data collection and consulting in real-time, providing important progress in the current quality assessment methods. The ***iTemp*** + is a totally wireless system which provides easy installation and configuration features.

IBM Watson IoT can be used as an IoT platform to supervise the environmental quality conditions of locations where technological activities are performed such as laboratories. For example, it can be implemented in laboratories where this IoT platform can provide an accurate association between the verified results and the environmental conditions. We conclude that IBM Watson IoT offers several advantages for connecting, device management, analytics and security. This platform not only supports easy and secure methods for device connection but also provides a configurable dashboard to manage the data storage, data transformation actions and third-party services integration. The IBM Watson IoT allows network and storage supervision and to define rules to trigger automatic actions that include alerts, email, IFTTT, Node-RED flows, and external services. When compared to several existing IoT platforms, the IBM Watson incorporates built-in artificial intelligence and blockchain support which are not implemented in similar platforms. In the future, the authors plan to use those resources for enhanced environmental quality prediction and security respectively. Technical enhancements to adapt the proposed solution to specific domains such as schools, laboratories and industry have been planned as future work. Due to the negative and significant effect IEQ in human behaviour, solutions as the ***iTemp+*** will lead to enhanced living environments and occupational health.

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