IoT Based Intelligent Building Applications in the Context of COVID-19 Pandemic

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***Abstract*— COVID-19 (Coronavirus) has affected our day to day life and the global economy and is far from being over. COVID-19 continues to spread rapidly around the world, more with the relaxation of restriction measures imposed by most countries. Limiting the further community spread of the epidemic has become a crucial issue, as employees return to office buildings. Technology, and especially intelligent building technology, can help to this purpose. Smart devices will have an important role to play in determining how the new normal workplace will function from now on. In this paper, we propose a solution for avoiding touching various objects and surfaces in offices, based on IoT. The system is called qToggle and provides a framework for efficiently and effectively interconnecting smart devices, equipping them with intelligence that helps automating many of the everyday activities in offices. Most qToggle devices are based on ESP8266/ESP8285 chips, Raspberry Pi boards and smart sensors. A mobile application allows users to control a series of appliances and sensors.**

Keywords*— *COVID 19, Internet of Things, automation, Smart buildings, BMS

I. INTRODUCTION

COVID-19 (Coronavirus) is caused by Severe acute respiratory syndrome - Coronavirus 2 (SARS-COV-2) virus and first appeared in China at the end of 2019. Since then it has rapidly spread to Asia and around the world, evolving into a huge pandemic. At the time of writing, according to Worldometers [1] and World Health Organization (WHO) [2], the virus has already infected more than 38 million of people around the world and more than 1 million people have died, as of October 2020. Even with the lockdown and the severe quarantine, COVID-19 continues to spread very fast and the world is struggling to control its spread, especially because many countries have already started to relax the restriction measures and to restart their economies. This means reopening the factories, the business centers with many offices and involving lots of people, and social distancing may not be enough. When more people are infected with coronavirus at once in a given area, the health-care systems risk to collapse and people who could have been saved in less demanding circumstances will die. Minimizing this impact requires a lot of attention from every single person. Finding additional solutions for slowing down the rate and the number of new coronavirus infections is crucial.

Beside the classical spreading methods, from person to person, COVID-19 also can spread from contact with infected surfaces or objects. For example, people can get infected by touching a surface or object that someone else touched after coughing into their hand and then touching their own mouth, nose, or eyes. The most commonly touched surfaces in offices, especially shared spaces, are light switches, doors, coffee machines, remotes, temperature thermostats. Minimizing the touching of objects could also minimize the virus spread.

A set of new technologies known as the Internet of Things (IoT) have gained global attention in the last years. The IoT is a system that allows devices with an on/off switch to be connected and remotely monitored across the Internet [3]. IoT uses the Internet Protocol (IP) to connect devices, which include smartphones, tablets and digital assistants to various types of sensors, appliances and systems such as lighting, temperature or security. Intelligent Building Management Systems (BMS) represent an important part of the IoT paradigm that aims to control and monitor the mechanical and electrical equipment of a building. Allowing objects and devices in a building to be connected to the Internet enables users to remotely monitor and control them. From light switches that can be controlled to turn on and off by using a smartphone, tablet, laptop or by voice command, to thermostats that will adjust the indoor temperatures, access control, or air conditioning on/off switching, intelligent BMS solutions have become popular in the last years and more nowadays, since COVID-19 outbreak. In addition to the increased protection given by automation, commercial and industrial consumers are also interested in energy-saving solutions, provided by BMS. Moreover, many firms, from the most affected areas, still maintain closed offices. Thus, managers and landlords need to find strategies to manage their empty buildings and ensure the control of risks that unoccupied buildings face, for example energy waste, theft, vandalism and fire. In the intelligent building world, remote management is a valuable technology that facilitates engineers to control, optimize and fix assets from off-site.

Fig.1 shows an example of an intelligent building employed with different IoT connected utilities. Although, it presents only a few examples, there are many more applications that can be implemented, upon request. This work presents a simple solution, called qToggle, that can be used for controlling devices in a building. qToggle is built around a flexible but powerful Application Programming Interface (API), allowing various types of devices to work together.

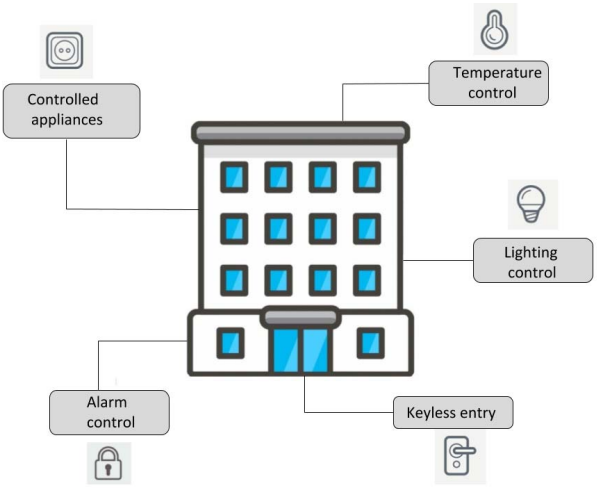

Fig. 1. An IoT based intelligent building depicting the use of smart sensing devices for different purposes.

We have deployed this solution to reduce the exposure and transmission of Coronavirus during the pandemic situation in workspaces by avoiding touching certain objects and surfaces. In addition, our solution can be also used for a higher efficiency in a building and for helping managing buildings during an emergency.

II. QTOGGLE SYSTEM ARCHITECTURE AND DESIGN

qToggle aims to propose a standard that allows managing, provisioning and talking to different devices. qToggle does not attempt to reinvent the wheel, but it makes use of the existing and widely used technologies. The classic Ethernet and/or a Wi-Fi local network are usually enough for a working qToggle setup. The different hardware used in the system are: Raspberry Pi 3 or 4 boards (any model), ESP 8266 Wi-Fi modules and smart devices.

The Raspberry Pi is a low cost, miniature sized single-board computer developed in the UK by the Raspberry Pi Foundation, capable of performing all functions of a normal computer. The Raspberry Pi is an open source hardware technology which combines a programming language and an Integrated Development Environment (IDE) [4-5]. The reason for choosing Raspberry Pi boards, other than the low price, is the energy efficiency and the programming facility (Raspberry Pi uses Python, a programming language with relatively fewer lines of code and less complexity). Moreover, most of the software and projects done on Raspberry Pi are open source and are maintained by online user communities, always excited about new projects.

The three roles of the Raspberry Pi board in a qToggle setup are the following: the board could act as a qToggle device when it is equipped with peripherals (sensors or relay boards), it could also act as a master hub for other qToggle devices and, finally, it could help installing the ESP firmware on some devices, when running Tuya Convert OS. Tuya is a Chinese smart devices platform that offers cloud services for, among others, ESP8266/ESP8285-based devices.

The main part of an automation system based on IoT is the microcontroller. The ESP 8266 Wi-Fi module represents a set of performant highly integrated wireless System on Chip (SoC), that provide a complete and standalone Wi-Fi network solution [6]. ESP8266EX version is one of the most integrated Wi-Fi chips in the industry.

Devices used with qToggle are usually sensors and actuators with an upstream network connection. Most qToggle devices are based on ESP8266/ESP8285 chips or on Raspberry Pi boards. Keeping the device firmware up to date represents an essential task, that is often neglected when dealing with large fleets of devices. qToggle facilitates this task by allowing updates of the firmware in a common way for different types/models of devices.

The idea behind qToggle is to control programmable systems having a TCP/IP stack via simple HTTP requests. These systems can be, for example, single-board computers or TCP/IP-enabled microcontrollers. API specifications seem complex, offering many functionalities and use cases. Yet, most of them are optional, only a small set of functions being mandatory for implementing qToggle.

III. QTOGGLE APP

Workplaces are prime locations for viruses like COVID-19 to spread, so businesses are trying to find out how to ensure the security of their physical spaces. Since social distancing is extremely critical to prevent the spread of coronavirus, limiting the items people touch around the working space is essential. The proposed automation system can be monitored and controlled very easy, using a mobile app (and its associated ecosystem). It provides a friendly user interface, called frontend, which comes in the form of a progressive web application (PWA). qToggle is designed to be used on smartphones, tablets and just as well on laptops/desktop machines.

qToggle has been designed as a way of interconnecting sensors, actuators and other data sources with the purpose of multiple automations. It is in fact an extensive automation project.

Firstly, the app should be installed and, being a PWA, it should be simply added to the home screen of the mobile phone. After installation, qToggle app will be found through the apps list of the device, and it can be uninstalled any time the used wants to. When prompted for login for the first time (see Fig.2), admin with empty password should be used, but it is highly recommended to set proper passwords in the Settings page of the app, for obvious security reasons. In panel edit mode, the user can add, move around, resize, remove and configure widgets. Widgets usually require selecting one or more ports, whose values will be displayed and/or changed by the widget upon interaction.

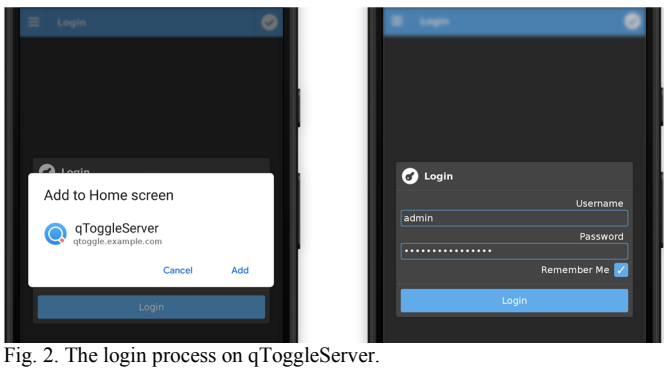

Fig. 2. The login process on qToggleServer.

The ports section is only accessible to administrators and allows adding, removing and configuring ports. Also, only administrators are allowed to add, remove and configure slave devices.

qToggle app features are shown in Fig.3.

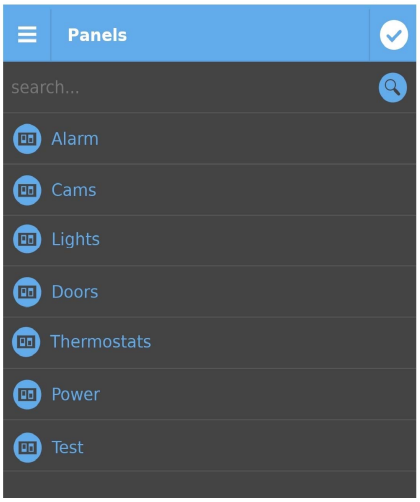

Figure 3. qToggle app features.

At this moment, qToggle can be used for the following purposes in a building: remotely controlling the indoor temperature (thermostats) in each room/office, controlling the lights (turn on-off) by voice command or from the app, controlling the A/C, monitoring the power in the building, access control (open-close different doors of the building) by voice command and through the app, security (arm, disarm the alarm).

Some examples from qToggle app are given in Fig.4. The app can be particularized for each user according to necessities.

A. Controlling temperatures and A/C

Indoor temperatures are controlled in order to maintain thermal comfort and to save energy cost. The thermostats system on qToggle offers the following advantages: it is touch free (the user controls thermostats using his own device and the qToggle app), the ability to access and control the indoor temperature anytime and from anywhere, the ability to monitor and differentially set the temperature in individual offices (not every room has the same heating requirements, for example servers room or bathrooms have different requirements than an usual office), it enables scheduling (lower the temperature during the night, when nobody is at work, or during lockdown) and thus it eliminates manual adjustments to save time and effort. Thanks to the temperature sensors, the heating system will start only when the temperature falls under a set value (this value is set on qToggle app for each room).

The air conditioning can be turned on and off without passing the remote from hand to hand, but using the app. This can be done using a smart plug for the A/C machine. Currently, the user can switch on and off the A/C, since the app is used in a residential home for the moment and we prefer a constant temperature from the A/C. Controlling the degrees is a feature that can be very easy implemented in qToggle and it will look similar to the case of thermostats (see Fig.4). These functionalities can be extended to other appliances in an office very simple.

Fig. 4. Examples of qToggle features in a working space.

B. Access control and security

Access control involves controlling the gates and doors, without touching the handles, which are maybe the most touched objects in an office. With a fully automatic system, people no longer need to touch door handles, giving them germ-free access in the building and offices. Access control can be done manually, by using the qToggle app and vocally,

using Google assistant and certain commands established by the user.

Every security system in a building consists of a master control panel, the keypad (touched by people when entering the code), motion sensors and the siren. In qToggle app there is the possibility to arm and disarm the security system without touching the keypad. Arming and disarming are performed manually using the qToggle app and mobile device and by voice commands, using Google assistant on a smart watch for example.

C. Controlling the lights

One of the main advantages of smart lighting control systems in this pandemic situation is, by far, the contact avoidance, and thus an increased protection between employees. Another advantage is related to energy saving, which has become more relevant since a lot of businesses have received lower incomes during the lockdown period and thus saving money has become an important topic. Big buildings, with many offices, can waste a lot of energy by simply leaving the lights on where they are not needed. Also, many people forgot the lights on somewhere in the building, when leaving. So, in these cases, it is easy to see where lights are on and to control them from a mobile app.

The lights can be controlled through voice command as well, for example using a phrase such as "turn on/off the light in ...room/office", using Google Home assistant (it is compatible with Amazon Alexa too).

D. Power monitoring

One of the goals for monitoring the power is to see how much energy the building is using and to become more aware of the energy use and, thus, of the money spent on energy. Another feature of an electricity monitor is the help in identifying any power-hungry appliance accidentally left switched on during weekends or lockdown. A smart power meter allows a continuous monitoring of all the important parameters when it comes to electricity: active, reactive, or apparent power, power factor, current, voltage, frequency, and total energy consumption. The device we used and proposed is based on ESP8266 and integrates a high current switch that can be used to remotely cut off energy supply in case of an emergency.

IV. Conclusions

In the present pandemic situation, all countries of the world are fighting against COVID-19 and are looking for practical and cost-effective solutions to face the problems arising in several ways. The focus post-lockdown is to create a safe working environment for employees and intelligent buildings are already capable of integrating technologies that can provide this level of safety.

Cleaning and disinfecting high-touch surfaces could be exhausting sometimes, so a solution for avoiding touching certain objects and surfaces could provide increased protection and comfort in an office. Using smartphones or personal computers, several devices can be controlled according to the user's wish with complete accuracy, and this will avoid touching the objects in the workspace.

In this project, we proposed a simple solution for building automation based on ESP8266/ESP8285 chips and Raspberry Pi boards. Both choices are cost effective, small and easy to work with. Our aim is to make qToggle a smart prototype, with various functionalities: automation, control, monitoring, and security, a system that could be continuously developed and improved, hence the choice of using Raspberry Pi and ESP Wi-Fi modules. Moreover, the proposed qToggle system uses a very basic core API, allowing for a more flexible network design.

Controlling the alarm before leaving the office, opening and closing the entry door, controlling the lights, thermostats, air conditioning, and even the coffee machine only by using the personal smartphone are only a few examples that are or can be implemented in qToggle.

One feature that will be soon added to qToggle is monitoring the air humidity. A high humidity causes condensation and mold, a low humidity increases the risk of respiratory illnesses, and allows viruses and germs to multiply. Thus, a humidity sensor will protect buildings and belongings by monitoring humidity levels and could be programmed to alert the customer in case the indoor humidity fluctuates to undesirable levels.

Air quality improvement through an increased ventilation and filtration (high quality filters) can help minimize the spread of viruses. For example, real-time alerts on qToggle regarding the indoor air quality (not only humidity levels) could be of real help. An ultraviolet (UV) system (UV lamps) has been shown to reduce infections from other viruses. These appliances can easily be controlled through the app (by using smart plugs) and turned on after work (including schedules), so the next day the workplace will be sterilized.

Another feature that could be easily implemented in qToggle is related to thermal cameras used to identify people with fever. The high-performance infrared thermal cameras can be installed at the entrance of the building and connected to qToggle. Rules can then be configured to prevent access to persons having body temperatures above certain thresholds. This will reduce the potential exposure to infection associated with manual temperature checks and the possible interaction with the other employees.

References

[1] Coronavirus Worldometer https://www.worldometers.info/coronavirus/ ; *accessed October 2020*.

[2] World Health Organization (WHO). Novel Coronavirus (2019-nCoV) situation reports. 2020. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports; *accessed August 2020*.

[3] S. Vashi et al., "Internet of Things (IoT): A vision, architectural elements, and security issues," Proceedings of the International conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud), pp. 492-496, 2017.

[4] https://engineering.eckovation.com/raspberry-pi-project-home-automation/

[5] E. Upton and G. Halfacree, Raspberry Pi User Guide. A John Wiley and Sons Ltd., 2012.

[6] https://www.espressif.com/sites/default/files/documentation/0a-esp8266ex_datasheet_en.pdf, *accessed October 2020.*