Covid-19 temperature monitoring device IOT system design report

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Summary

The main purpose of this project is to design and implement an IoT prototype device for a local company in order to measure employee's temperature for Covid-19 monitoring purposes.

This will be achieved by using low-cost micro-controller such as Arduino, the employees will present their RFID card to the device to gain access to the building, the device will measure their body temperature and will allow them to enter the place just if their bodily temperature is within the acceptable range.

IoT devices have added values to people's life where it allowed them to manage their life automatically and remotely. The internet of Things connectivity is applied in the designed prototype, so the employee's ID and temperature information will be sent over the local network using a webpage and over the internet.

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1.0 Introduction

Covid-19 has significantly affected everybody all over the world where lockdowns were imposed in every country to prevent the spread of the virus. To help companies and employees to continue working safely, this project was provided.

The design meant to build a prototype of a device to measure employees' temperature which achieve cost efficiency and low power consumption. The Aston IoT trainer board is used, which contains ESP8266 micro-controller, RFID chip, potentiometer, LCD, and LED. In the designed prototype the potentiometer represents the temperature sensor and LED represents the entrance door.

2.0 Design and implementation

As a prototype design to measure the temperature, a thermal infrared temperature sensor can be used, it can be placed on the entrance, when the person presents his ID card his temperature will be measured from either his head or hand where the sensor can be placed close to the RFID, the temperature can be taken from the hand. The device can be powered by the main power supply from the company itself, but there will be need for a battery if a cut in the electricity happens.

The general operation steps of the device or the functionality of the system are explained as following:

1) Connect to MQTT using **MQTTconnect()** function.
2) Subscribe to MQTT using **MQTT.readSubscription()** function.
3) The RFID will be checked if any card is presented every 100ms using **CheckRFID()** function, at the same time a message will be presented on the LCD telling employees to present their ID cards.
4) If ID card is presented, the temperature, which is represented by the potentiometer value in the prototype, will be measured and the ID number will be redden. If no ID cards presented the device will continue checking the RFID. The temperature value will be displayed on LCD for 2 seconds.
5) Lower and upper limits are defined as 36.5 and 38 respectively, if the measured temperature is within this range the LED will be turned on for 1 second, if not a message on LCD will be displayed saying "High Temperature!"
6) The temperature and ID information will be sent to MQTT using **Temp.publish().**
7) Check HTTP server every 300ms using **server.available()** function, if it is available it will get HTTP request and update temperature limits.
8) HTTP webpage will be updated will the last 10 access attempts using **servepage()**.

The device operation algorithm is demonstrated by a flowchart in Figure 1.

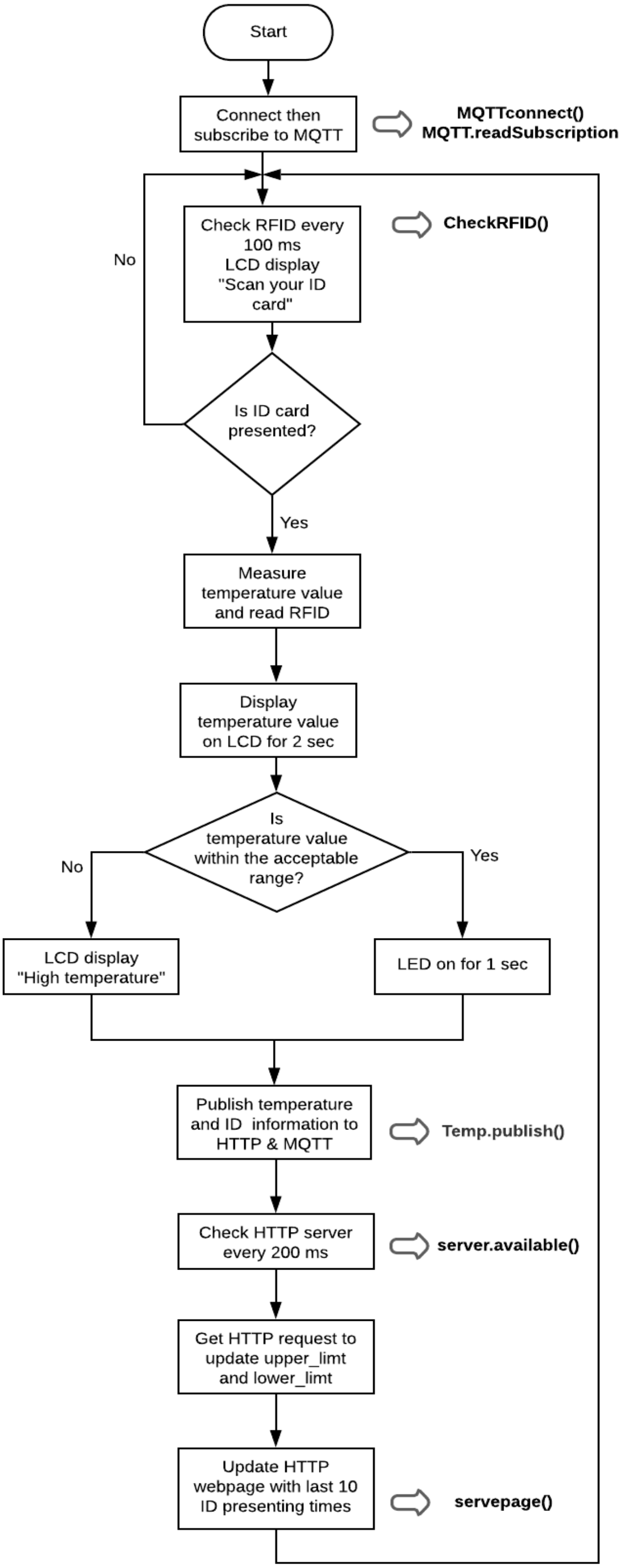
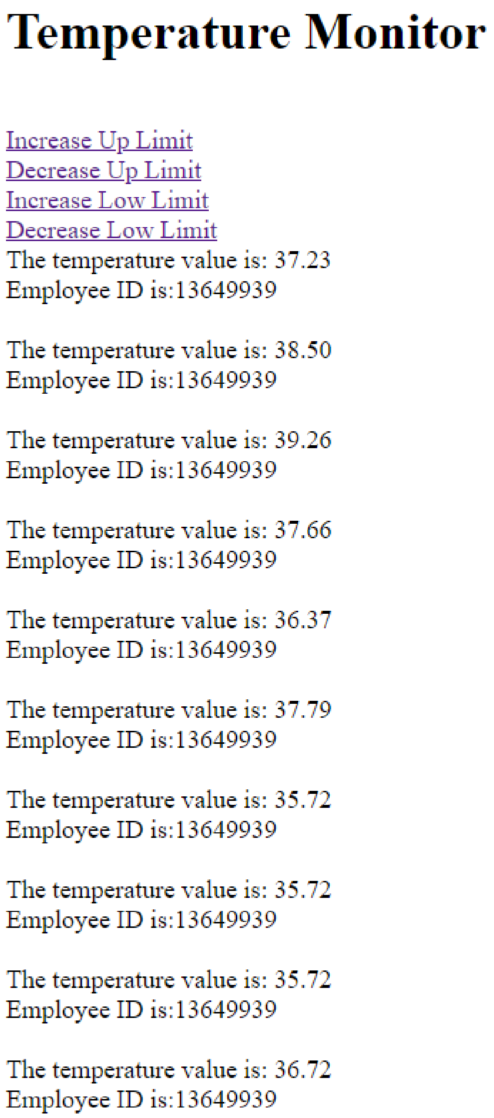


Figure 1: Flow chart of the system

The following figures illustrates the collected data after it is sent over the webpage (through HTTP) and the internet (through MQTT).


Temperature Monitor

Increase Up Limit
Decrease Up Limit
Increase Low Limit
Decrease Low Limit
The temperature value is: 37.23
Employee ID is:13649939

The temperature value is: 38.50
Employee ID is:13649939

The temperature value is: 39.26
Employee ID is:13649939

The temperature value is: 37.66
Employee ID is:13649939

The temperature value is: 36.37
Employee ID is:13649939

The temperature value is: 37.79
Employee ID is:13649939

The temperature value is: 35.72
Employee ID is:13649939

The temperature value is: 35.72
Employee ID is:13649939

The temperature value is: 35.72
Employee ID is:13649939

The temperature value is: 36.72
Employee ID is:13649939

Figure 3: The result of sending data over the webpage (HTTP)

Figure 2: The data results of sending over the internet (MQTT) using Adafruit dashboard

3.0 Societal, privacy and commercial impact analysis

In order to analyse the impact of the device, the following aspects should be considered.

3.1 Societal impact:

Technology has a massive effect on the society, this impact has even increased after the introduction of IoT technology. So, it is crucial to analyse how the device will help people in their life, what is the possible drawbacks it could affect the society and how the device could be improved to adapt people's life.

The temperature monitoring IoT device will help to decrease covid-19 cases by detecting any temperature out of the normal range for the employees when they try to enter the workplace, therefore it will be easy to detect the virus and isolate the infected people, it also helps companies to interact with employees in a more secure way following the guide lance to prevent the spread of the virus. The access to enter the company will be given to employees who have acceptable temperature range, who have a high temperature will be sent a message to go home and isolate themselves. The ID and the temperature information will be saved and sent over the network for monitoring purposes, this will help to track the possible covid-19 cases in the company. Moreover, the large data that was collected can be used for statistical purposes to understand the spread of the covid-19 among employees in companies where there is a huge number of people work in the private sector.

However, there will be some societal problems that the device or the collected data could cause, one of these problems is that some people will not accept to share their data for privacy reasons, despite the big advantage of the device of detecting the possible covid-19 cases. Furthermore, if the pandemic is over, the large amount of data was collected will not be needed, also when the data amount increases, more storage space will be needed and there will be a decent amount of data vulnerable to cyber-attacks through internet. To solve these problems, it is suggested to make a data life cycle of one or two months and improved cyber security should be used to encrypt the data from cyber-attacks.

3.2 Privacy impact:

Privacy and data protection have become a concern after this increase of IoT devices, where a massive amount of personal data of individuals is collected and transmitted through the internet. For this reason, the IoT devices should be provided with data encryption system to protect individual's information.

The designed IoT prototype collects employees ID and temperature data and sends it to the local network using HTTP protocol and over the internet using MQTT. HTTP is a protocol used to transmit data over the local webpage using request and response messages; request is the message sent by the client (web browser) and response is the message sent by the server as an answer. MQTT (Message Queuing Telemetry Transport) is a messaging protocol which uses publish / subscribe pattern, meaning that there is no communicating with the server, client devices publish and subscribe to topics managed by a broker [1]. HTTP does not use any encryption protocol, in this case anyone is monitoring the session can read all the request and responses which has confidential information about employees, using this protocol can allow employees in the company to change information such as temperature and personal ID of others. On the contrary, MQTT uses a strong encryption protocol such as SSL/TLS which uses public key encryption; the public key is shared with client application through server's SSL certificate, when the client wants to send the data to the server a new key will be obtained using the public and private keys, the new key is called session key [2]. in this way the data of employees will be protected, and no one can read it.

The privacy concern can be solved by using MQTT protocol which provide reliability, flexibility and simplicity. Another option for more secure way to send the data is using HTTPs instead of HTTP to send data over local network, it is basically the same theory as HTTP protocol, but it uses SSL/TLS encryption, the "s" in HTTPs refers to secure, the main concept of data encryption used in HTTPs is public key encryption method as explained before.

Before releasing the product to the market, Privacy impact assessment (PIA) should be applied to prevent any possible privacy issue. Moreover, privacy by design fundamentals should be considered, it employs the approach of proactive rather than reactive measures, it means to study or anticipate all possible security risks that could happen and prevent them from occurring. Also end to end security should be considered, this means full lifecycle protection should be provided, the data should be securely kept and at the end of the process it should be destroyed after a period of time (e.g., 1-3 months) to protect individuals information, this also helps to get rid of the large amount of data possessed and save storage.

3.3 Commercial impact:

After evaluating many crucial aspects of the IoT product technically, the potential impact and commercial feasibility of the product must be studied before releasing the product to the market, this includes estimation of the amount of investment required and how much money can be obtained from the IoT product, to estimate these aspects, the targeted market should be considered by assessing similar products and market sizes so the possible revenue from the product can be estimated. Before going into the commercial feasibility study a SWOT analysis will be performed to understand the product's strengths, weaknesses, opportunities, and threats.

The IoT temperature monitoring product has many strengths in its design and functionality. As mentioned in the previous sections that the IoT temperature monitoring product has the availability to collect temperature values of employees and send it with their IDs over the network, data collection occurs immediately when the employee presents his ID card and without any human need the temperature value will be calculated, it is the opposite of other temperature sensing devices where a person has to hold the device and point it to the customers to measure their temperature as it is seen in the working places nowadays. compared with other temperature sensing devices such as thermal cameras, covid-19 temperature device is very cost efficiency while advanced thermal cameras cost a fortune, it also provides portability and low power consumption. However, as explained in the previous section (Privacy impact), there is no encryption used when data is transmitted over the local network, solution were provided such as using HTTPs. Also, the temperature measurement could be more accurate, the device can be developed, and more features could be added to increase accuracy. Discovering a vaccine for coronavirus would be the threat on this device where less companies would buy it.

When studying the market size, there is three types of markets should be considered which are the Total Addressable Market (TAM), Serviceable Attainable Market (SAM) and Serviceable Obtainable Market (SOM). TAM is the total market size available can be reached, SAM is the market size that can be accessed using available trades networks, in this project case it can be imagined as the UK, both TAM and SAM presume a singular company. SOM is the market size of SAM that can be easily reached, it can be imagined as Birmingham where the device is produced. According to global market report, it is seen that the global temperature sensing market size was 6.3 billion USD in 2020 and it is estimated to grow with a compound annual growth rate (CAGR) of 4.8% to reach 8.8 billion USD by 2027 [3], it also shows that the market size of Europe is 1.5 billion USD means that it is 23% of the total market, if the UK has 20-30% of the European market means that the market size of the UK is around 450 million USD, in this case Birmingham is estimated to have around 30% of the UK's market, means that the market size of Birmingham is 135 million USD (97031553.22£). In this case, SAM is represented by a percentage of the UK's market size of the total market size, where the UK has 5-7% of the total market size, SOM is a percentage of SAM where about 25-30% of the UK's market can be reached represented by the city of Birmingham.

To be able to estimate the number of sales that could be made, it is required to calculate the product price which can be estimated as following:

Component	Price (£)
ESP8266 micro-controller	8.5
Infrared temperature sensor	6
RIFD reader	6
LCD	3.5
Battery (if required)	5
Engineering and installation costs	10
Total	39

Table 1: Product estimated cost

The device will cost maximum **39 £** in total and it can be sold by **100 £.** So, the number of sales that could be made can be calculated as

Number of sales = SOM / product price

Number of sales = 97031553/ 100 = **970315.5** (Max. sales can be achieved).

The time required to bring such a product to the market can be estimated as 3 to 5 months, this period includes testing and improving the device, after this period, the device can be given as trial to some companies to try it as a marketing plan, also, free seminars can be given to companies about how to use the device.

Cash flow:

Month	1	2	3	4	5	6	7
Revenue							
Hardware sales	-	10000	10000	10000	10000	10000	10000
Total revenue	-	10000	10000	10000	10000	10000	10000
Funding							
Seed investment	10000	-	-	-	-	-	-
Total funding	10000	-	-	-	-	-	-
Cost							
Staff							
CTO	1800	1800	1800	1800	1800	1800	1800
Software engineer (part time)	900	900	900	900	900	900	900
Technician (part time)	-	700	700	700	700	700	700
Direct cost							
Materials & Manufacturing	-	3000	3000	3000	3000	3000	3000
R&D Costs							
Prototyping	150	150	-	-	-	-	-
Fixed costs							
Serviced office	300	300	300	300	300	300	300
Phone line	25	25	25	25	25	25	25
PC & Software	1000	-	-	-	-	-	-
Marketing							
Website	700	-	-	-	-	-	-
Digital advertising	700	500	500	500	500	500	500
Total cost	5575	7375	7225	7225	7225	7225	7225
Monthly Profit	5575	1800	1950	1950	1950	1950	1950
Profit to date	5575	3775	1825	125	2075	4025	5975
Cash flow	4575	1800	1950	1950	1950	1950	1950
Bank balance	4575	6375	8325	10275	12225	14175	16125

Table 2: Cash flow of the IoT product

4.0 EE4IOT ONLY – Deployment considerations

After studying the potential impact and commercial feasibility of the product, the device has to be analysed in term of deployment, this includes the connectivity method and the installation process. The connectivity means that how the IoT device is going to communicate with the router.

IoT based covid-19 temperature monitoring device is supposed to be installed at the entrances of any company, the suggested scenario is to connect the IoT device with the existed gateway in the company, assuming that 802.11n (2.4/5 GHz) router is already used in the company, this router has indoor range up to 70m [4], this means that one router is fairly enough for the company unless they have a huge space and many entrances, the number of routers can be increased. To evaluate the distance between the device and the router, Link budget calculations should be considered, using the specifications of ESP8266 micro-controller and 802.11n wireless router founded in [5,6] we can find the following values:

$P_{sen\,(esp)} = -91\ dBm\ , P_{sen\,(802.11n)} = -77\ dBm\ , P_{T\,(802.11n)} = 15.5\ dBm,$

$P_{T\,(esp)} = 14\ dBm,\ G_T = 2\ dBi\ \ ,\ G_R = 1.8\ dBi\ ,\ \lambda = 0.125\ \mathrm{m}\ ,\ \ d = 70m$

Assuming a line of sight (LOS) situation between the router and the device, the received power can be calculated as following:

- The received power at the IoT device:

$$P_{sen\,(esp)} = -91\ dBm = \frac{10^{\left(\frac{-91}{10}\right)}}{1000} = \mathbf{7.94\ \times 10^{-13}\ W}$$

$$P_{R(esp)} = P_{T(\,802.11\mathrm{n}\,)} \cdot G_T \cdot G_R \cdot \left(\frac{\lambda}{4\pi d}\right)^2$$

$P_{R(esp)} = \mathbf{1.7 \times 10^{-9}\ W}$, the received power to the IoT device.

- The received Power at the router:

$$P_{sen\,(esp)} = -77\ dBm = \frac{10^{\left(\frac{-77}{10}\right)}}{1000} = \mathbf{2\ \times 10^{-11}\ W}$$

$$P_{R(802.11\mathrm{n})} = P_{T(esp)} \cdot G_T \cdot G_R \cdot \left(\frac{\lambda}{4\pi d}\right)^2$$

$P_{R(802.11\mathrm{n})} = \mathbf{1.2 \times 10^{-9}\ W}$, the received power to the router.

In both cases, P_{sen} is smaller than P_R. This means that device can be place 70m away from the router (under LOS assumption), of course it is preferred to be closer and to use many routers if the place is huge.

To calculate the deployment costs many prices should be considered such as materials, production and installation costs, materials cost was shown in table (1) where it is around 24 £, production cost includes the PCB circuit design and printing which cost around 10 £, installation also costs around 10 £.

Before calculating the running cost per year, the power consumption of the IoT device should be calculated. This can be achieved by calculating the power consumed in each component of the device, to do that the current passes through these components should be estimated first. By looking at the datasheet of each component, we can find that the load current of the micro controller is ***56 mA*** [5], the LCD has a current draw of ***60 mA*** according to [7], while the temperature sensor has current load of ***20 mA*** [8], in the RFID case it is ***10 mA*** [9].

The total drawn current is sum of the current drawn from each component which equals **146 mA**.

The total power consumption can be calculated by $\mathrm{P} = \mathrm{V} \times \mathrm{I}$

$\mathrm{P} = 3.3 \times 0.146 = \mathbf{0.48\ W}$

After finding the power consumption of the IoT device, the running cost per year can be calculated, as the year has around 260 working days and by assuming that the working day is 8 hours, the IoT device power consumption per day can be determined as $0.48 \times 8 = 3.84\,W = 0.0038\,kW$, where the average price of electricity in the UK is 14.4 pence per kWh [10]. So, the running cost per day will be $0.0038 \times 14.4 = 0.054\,p$, and **the cost for one working year** will be $0.054 \times 260 = \boldsymbol{14.22\,p}$.

The device can be improved, and many features can be added to the device one of them is OTA programming, this allows the user to upload a new program to the ESP8266 using Wi-Fi instead of connecting it to the computer using USB cable to upload the code. However, this will increase the security concerns, for that the data can be only sent through HTTPs and MQTT where they have a strong encryption system.

5.0 Conclusion

It can be concluded that the IoT based temperature monitoring device will be a helpful solution to prevent the spread of Covid-19 virus and the device design achieves cost efficiency and low power consumption.

The operation functionality of the IoT device were illustrated and a block diagram of the algorithm was provided. The societal and privacy impacts were discussed where the device has many benefits societally, however in term of privacy, it is not secure to use HTTP where it does not have any encryption while sending the data over the local network, for that it is recommended to use HTTPs or MQTT for data protection purposes. The potential impact and commercial feasibility of the product were studied where the targeted market was defined and the maximum numbers of sales where calculated based on an estimation of the market size, the cash flow shows that after three months there will be a profit from the device. The connectivity method and the installation process were discussed where the running cost per year was calculated based of how much power it consumes.

The IoT based Covid-19 temperature measuring device is considered a great and cheap option to provide a workplace clean from the virus.

6.0 References

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