EE4IOT system design report

Submitted by Muhammad Aizaz Afzal
Student # 200261713

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Summary

This report contains detailed information about the device called AntiSars, which has been designed to help prevent the spread of covid-19 by identifying the employees/potential virus carriers through measurement of body temperature using infrared temperature sensor and RFID card reader module.

Insights regarding societal, privacy and commercial impacts of this product are also discussed whereas the design and implementation part is described in great detailed with the help of designed dashboard, flowchart, and block diagram.

Power and link budget calculations are done to estimate the feasibility of installing AntiSars at Birmingham Museum and Art Gallery.

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1.0 Introduction

COVID-19 Pandemic has reshaped the world, it has changed the way of life forever. Like all other safety measures such as PCR/Rapid testing, wearing face masks, social distancing, washing hands and contactless payments, body temperature measurement is also a way to avoid potential virus spread. Almost all indoor facilities such as offices, educational institutes, libraries, supermarkets, train stations, airports etc have some sort of body temperature measurement system in place and it might not be 100% effective to identify potential virus carriers, but it is one of the easiest and quickest method to curb the virus spread.

A similar temperature measurement and attendance system is being designed for the employees and members of the Birmingham Museum & Art Gallery. The basic idea of the whole system is that every employee will be issued an RFID card which they will use to enter the premises. Upon scanning the RFID card, their body temperature will be recorded and displayed on the screen, if it is within the allowed range then the door will be opened, otherwise they will be asked to return home, perform rapid test and self-isolate.

In this report, you will find a detailed design and implementation section, societal, privacy and commercial impact analysis of the product and the deployment considerations of it.

2.0 Design and implementation

A prototype of the device, named **AntiSars,** is designed using ESP8266 microcontroller which supports WiFi connection, RFID card sensor and the values from potentiometer are modelled as values from an infrared thermometer such as Melexis MLX90614 Non-Contact IR Temperature Sensor, it is powered up using 5 VDC supply (runs at 3.3 VDC) which can make it a stand-alone battery powered device, or it can use the mains AC supply and convert it to acceptable level of DC using an adapter.

When the device is turned on, it connects to the internet using WiFi connection, it also establishes connection to a dashboard using MQTT and to a separate webpage using HTTP, after establishing connection, the acceptable body temperature range can be selected using either dashboard or the webpage it asks the user (employee in this case) to scan the RFID card, upon scanning it takes the body temperature of the user and compares it with the selected acceptable body temperature values, if the body temperature of the employee is within the acceptable range then the door opens otherwise the employee is asked to return home and self-isolate.

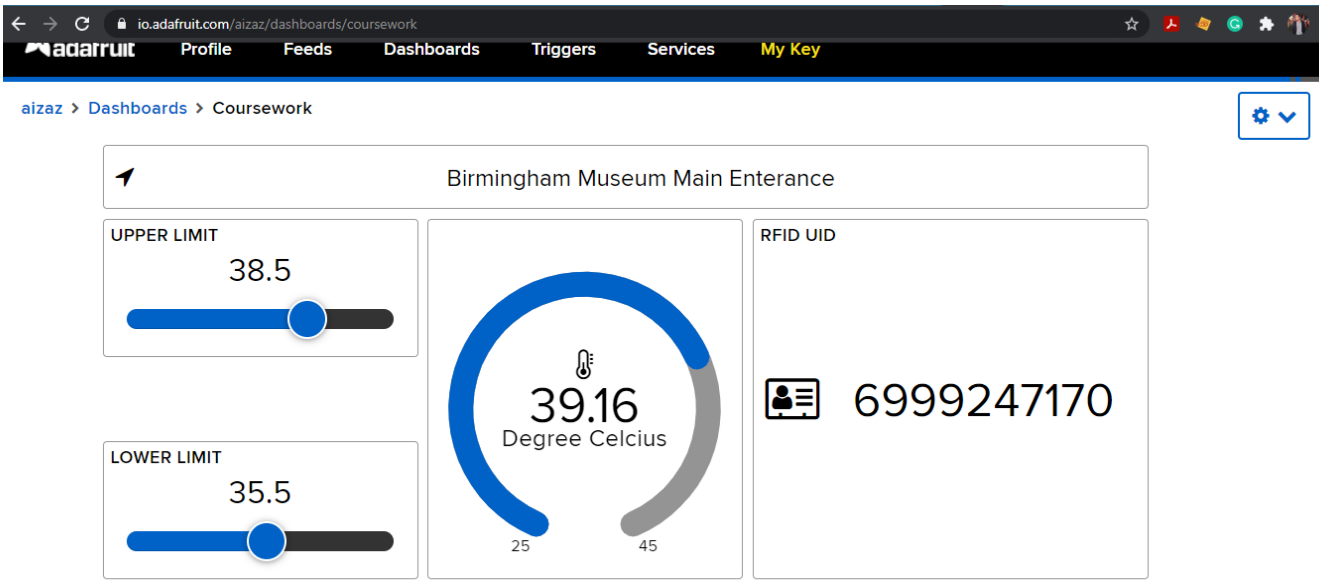

Figure 2 Dashboard using MQTT

The actual implementation of the project will use an infrared thermometer placed right near the RFID scanner and this infrared thermometer module will be connected to module, the LCD will ask the employee to move his face near the infrared thermometer so that the body temperature can be recorded. After measuring the temperature, the UID, device location and temperature value will be transferred over the local network using a webpage (using HTTP server) and over the internet (on a dashboard) using MQTT with SSL/TLS, the webpage will display the last 10 access attempts along with their UIDs and recorded temperature.

Figure 1 Webpage using HTTP

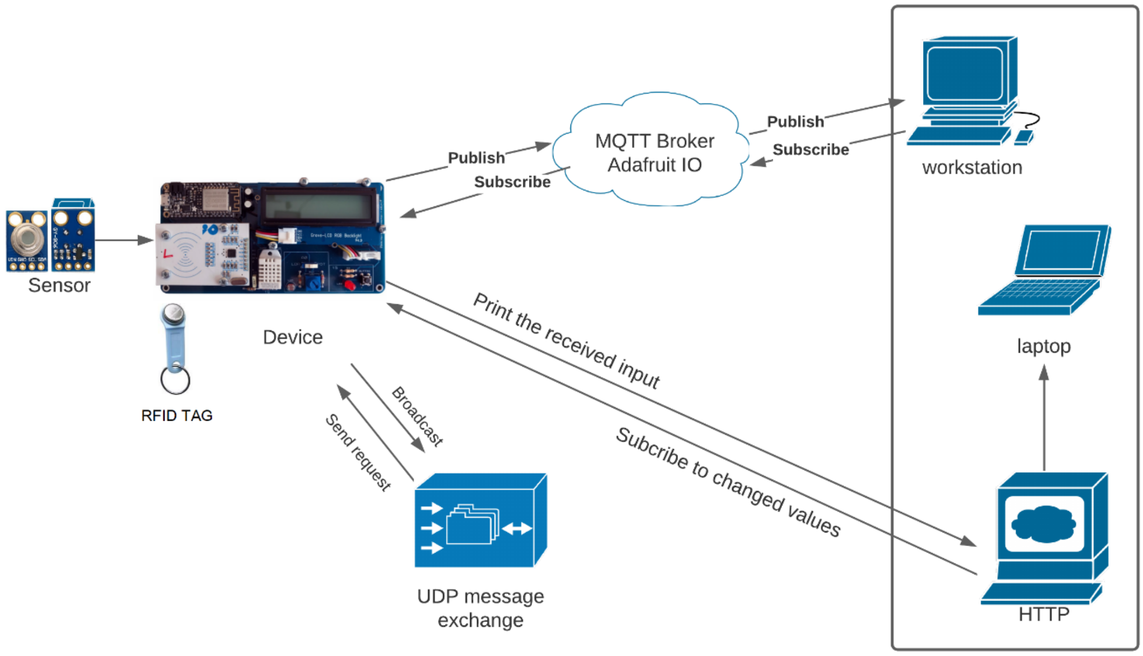

Figure 3 Block Diagram of AntiSars

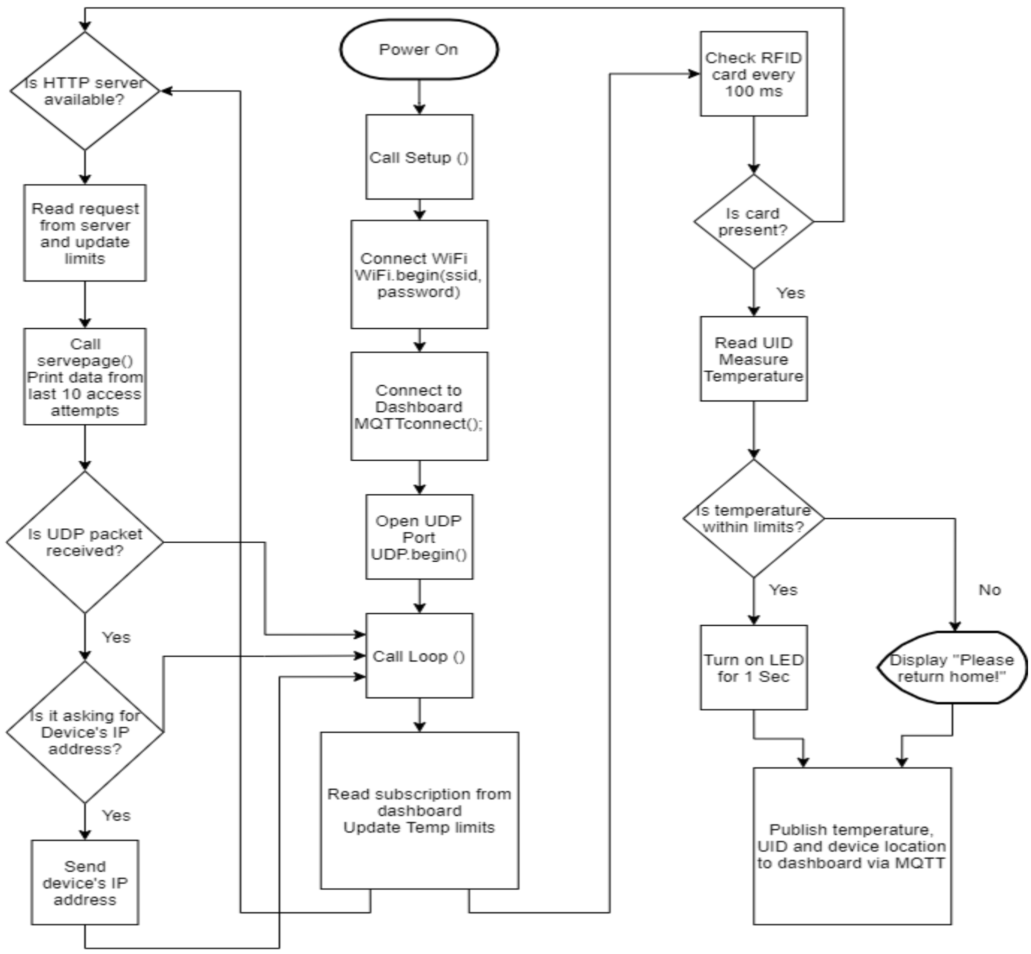

Figure 4 Flowchart of processes executed

3.0 Societal, privacy and commercial impact analysis

All IoT devices have societal and privacy concerns because they all record personal identifying information using sensors and transfer these over the internet, different devices are connected with each other (M2M) without significant human interaction and many times vulnerable to hacking. IoT has its own anticipated and unanticipated challenges just like internet had (and still has) when people started using it so it is imperative to inspect and brainstorm these concerns thoroughly so that IoT devices can be made secure and future proof.

To make a fair comparison, PESTLE analysis can be done to understand the external factors affecting this product and in general any IoT product. All the factors in PESTLE analysis can vary hugely from one country to another and so this report focuses on Pakistan but also discusses different factors in general.

Political Factors:

Since the device is being placed in the museum, there might be a lack of trust on the local administration because of fear of surveillance because using IoT devices makes it much easier to spy or steal sensitive information.

Political will to implement IoT is an important factor in success of IoT in general because if the political leaders are not literate enough or they are not updated with new technology then its highly likely that they would resist change specially the change which is difficult to comprehend for them. Corruption can also hamper the implementation of this IoT product because if the regulatory bodies are likely to ask for bribe for very basic things such as safety test of this product, then it is very difficult for a new company/start-up to survive in that kind of environment. Another aspect is that some elements in government can favour specific individuals/competitors.

If the political leadership understands that benefits of IoT outweigh the cons of it then they can facilitate in terms of trade laws, taxation relief, intellectual property rights protection and funding for start-ups.

Economic Factors:

IoT technology is predicted to provide around $15 trillion worth economic value by the end of this decade according to a recent study by deloitte [1] hence it will be the biggest industry in near future and there is a huge room for success in this industry. Although there are some economic concerns as well which may slow down the success of this product and IoT in general, after the Brexit, it is difficult to cope up with new trade laws and taxation. If this product (in future) requires components to be imported from EU then new taxes will have to be paid for import which will increase the cost of production, similar is the consequence of inflation rate which rose from 0.9% in 2020 to 1.5% in 2021 and is expected to reach 1.9% by 2023 in UK [2], the overall cost of this device will increase with rise in production cost, labour cost, transportation cost, sales, and marketing cost.

Because of economic slowdown in 2020 and partial recovery in 2021, in the world and in UK as well, the companies are more likely to invest in assets rather than keeping their money in the banks since the interest rates are low, so there is a high chance that companies would like to invest in this product because ultimately this product will give them a chance to concentrate on other important aspects of their business rather than worrying about the spread of virus at their workplace.

Introduction of this device can replace the individual taking temperature manually this has 2 benefits to the company, first is reduction in monthly payroll amount because now a separate employee is not required to take temperature, secondly, if a person takes the temperature manually there is a high possibility of virus spread. It also helps the company in monitoring the attendance of their employees in a much more efficient way because now they do not have to fill time sheets because this is an automated process, and they can have all the data stored on the Internet which can be checked at any time. On the other hand, introduction of this device at workplaces can contribute to unemployment which is generally a fear in case of almost all IoT devices because the processes are getting automated and less manual work is required to monitor them.

Social Factors:

With a fast-growing world population, it is important to place this device around the cities in offices, libraries, workplaces, and worship places etc so that the virus spread can be curbed. **AntiSars** has been made user friendly so that every employee/user must do minimum effort, even then, not everyone is technology savvy specially the older generations hence they might find it difficult to follow the directions displayed on the device and it might not perform optimally. In some cases, when an employee's temperature is not within the allowed temperature range, they will be asked to self-isolate, at this point they might feel that they are completely okay, and the device is wrong. These problems can be approached by giving employees a brief introduction to the device, how it works and how and why its beneficial for them. A small guide with directions can be printed next to the device.

The backend configuration is not user friendly therefore in case of device malfunctioning or to change parameters in the device, the office management can not to it by themselves, the installation company will have to be called.

Technological Factors:

Like all other new technologies, it is important to get this device patented, it is particularly important in today's world because the resources are available very easily on the internet and can be copied easily. The regulatory bodies need to play a huge role here to safeguard and protect new, small companies so that they can focus on developing new products rather than focussing on fear of getting their idea stolen.

This device opens a new approach to employee attendance system as well, most of the workplaces use biometric verification-based attendance systems but these are extremely dangerous and in current scenario as it can contribute to virus spread (fingerprint scanners), another big concern is that biometrics can be stolen from the network which has the most important data points for every human [3]. The future versions of this device will require new and updated components hence it is important to use the latest available components for best results.

Legal Factors:

With increased covid related SOPs, companies are legally required not to allow those employees to work from office who are suspected to have been infected by virus therefore this device is very useful in this scenario. Body temperature is private information [4] hence not every employee might be willing to give this information specially if they suspect it can be stored and used against them in any way so It must be made sure that employees' consent is taken before implementing this system.

Another important factor is the acceptance level of technology in the society, in the UK, people generally show acceptance towards new technology hence this is a very encouraging sign for this device although in third world countries it is the opposite and people are generally reluctant towards accepting change.

Environmental Factors:

Weather can have a big affect on any IoT device, if the weather is too hot and humid then the device can malfunction because of overheating, it is not waterproof, so it is difficult to place it outside the main gate specially during rainy season.

The device uses battery which has a limited life and needs to be disposed off or recycled properly, electrical waste is another concern but the WEEE Directive and RoHS Directive are tackling the issue of growing waste from electrical and electronic equipment (WEEE) [5], so it is important that this device also passes all the safety tests and has a sustainable life cycle therefore the battery is placed just as a secondary power source hence it will be replaced after a long time and the old battery will be disposed off as per directions of WEEE directive. This device will replace manual paperwork for attendance record and decrease the number of devices involved in the whole process thereby decreasing the carbon footprint.

Privacy Aspects:

Like all other IoT devices, this device also has some privacy concerns, to make the device protect against any privacy concern, guidelines of General Data Protection Regulation (GDPR) must be followed, GDPR is the European law on data protection and privacy. It is important to collect only relevant, adequate, and limited data and should be used only for the purpose they are processed [Article 5.1.c of GDPR] [6], Data should be stored for a limited time only according to Article 5.1.e of GDPR.

Therefore, device uses only 2 personal data points of the user:

1) RFID UID

2) Temperature

Risk	Risk Sources	Threats	Impacts	Controls	Severity	Likelihood
Illegal access to personal data	Hacker, employee, acquittance or an organisation	Data theft, data leak, identity theft	Blackmailing, threats, identity duplication, loss of employment, phishing, access to personal accounts	Data storage is kept to a minimum (only last 10 access attempts), SSL/TLS encryption, WiFi password protected, Data anonymisation, use of HTTPS	High	Maximum
Unauthorised access to premises	Hacker, member of public	Theft in museum, costly artifacts, painting stolen	loss of employment, loss of wealth and loss of historical/antique items	RFID UID randomisation after every few weeks, use of HTTPS	Very high	Low

Table 1 Risk analysis

Data from only the last 10 access attempts are stored on the microcontroller and transferred over the internet, anyone getting access to this information and employees' record can identify the employee using RFID UID, can get access to personal details of that employee such as full name, date of birth, gender, and age etc. Temperature is also considered as personal data point hence it is important to protect the security of this data.

The device uses MQTT and HTTP to send data over the internet and local network respectively, MQTT is Message Queuing Telemetry Transport, which is basically a publish-subscribe network protocol, and it uses TCP/IP in the transport layer. MQTT uses SSL/TLS (Transport Layer Security) encryption and encrypted port (8883) and broker's certificate's thumbprint. This makes sure that the device is relatively secure.

Commercial Impact Analysis:

Although **AntiSars** is still under development phase, there have been similar products made and they are available on the internet, but they are not available as a fully developed product [15][16][17] although It is important to know the commercializing aspects of it to find its commercial feasibility. Best way to do a market analysis is to calculate TAM, SAM, and SOM.

TAM is the total available market

SAM is the Serviceable Available Market

SOM is the Serviceable Obtainable Market

Due to Covid-19 there is a huge rise in demand for IoT based sensors, the global market is expected to grow from $8.4 billion in 2021 to $29.6 billion by 2026 with expected compound annual growth rate (CAGR) of 28.6%. [7]

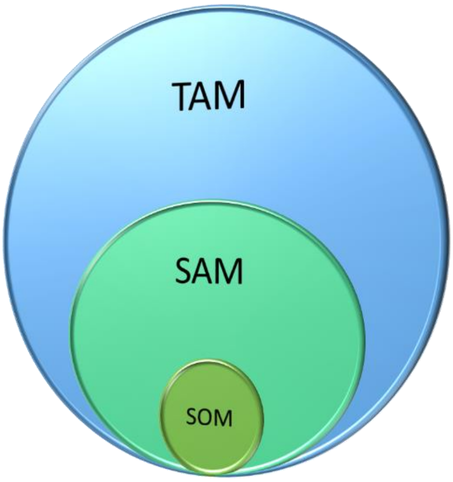

Figure 5 Market categories

Below is the table summarizing TAM, SAM and SOM of human body temperature measuring devices in 2021:

Table 2 Size of TAM, SAM, and SOM

Scope	Area covered	Size (Million USD)	Major players
TAM	World	8400	Philips, Omron Healthcare, 3M, Toshiba, Braun etc
SAM	UK	1028 (2020)	Invensys (Schneider Electric), Amphenol Advanced Sensors, Testemp etc [8]
SOM	Birmingham	57 (5.55% of UK Population)	Same as above

The above figures are estimates based on population size and reference provided above

Around 57 million USD (40.97 million GBP) is the Serviceable obtainable market of IoT based sensors, considering this number and the sales price of one such device (given in table below) we can find the number of units we can sell in one year.

Table 3 Components and prices

Component	Picture	Price (£)
Micro-controller (ESP8266)		16.63 [9]
RFID module (VMA405)		5.09 [10]
LCD (Grove 16 x 2)		6 [11]
Temperature Sensor (MLX90614)		9.02 [12]
Manufacturing and service cost [estimate]		10
Battery [Li-Po 1000 mAh]		7.50 [13]
LED		0.46 [14]
Total		54.7

Considering a profit margin of 46%, the sale price of this device will be 80 GBP

$$Maximum\ possible\ number\ of\ devices\ which\ can\ be\ sold\ in\ SOM = \frac{40.97 \times 10^6}{80}$$

$$= 512{,}125\ units$$

Table 4 Cashflow

Cashflow (All values are in £)							
Month	1	2	3	4	5	6	7
Revenue							
Units sold (estimated)		200	200	200	250	300	300
Total Sales Target (Units sold x Device price)		18000	18000	18000	22500	27000	27000
Total Revenue		18000	18000	18000	22500	27000	27000
Total Funding							
Seed Investment	18000						
Monthly Revenue	18000	18000	18000	18000	22500	27000	27000
Total Cost							
Payroll							
Chief Executive Officer (CEO)	2000	2000	2000	2000	2000	2000	2000
Design and Installation Engineer (part time)	1000	1000	1000	1000	1000	1000	1000
Project Manager (part time)	1000	1000	1000	1000	1000	1000	1000
Direct Cost							
Components & Assembling		10940	10940	10940	13675	16410	16410
Updating Cost							
Software Update				50			
Fixed Costs							
Office Rent	400	400	400	400	400	400	400
Phone Charges	30	30	30	30	30	30	30
Laptop & Office Equipment	2000						
Marketing							
Marketing (cold calling)	50	50					
Website	250						
Digital Marketing	300	250	200	150	100	50	
Total cost	6780	15670	15570	15570	18205	20890	20840
Monthly Profit	-6780	2330	2430	2430	4295	6110	6160
Year to Date Profit	-6780	-4450	-2020	410	4705	10815	16975
Cash Flow	-6780	2330	2430	2430	4295	6110	6160
Remaining Bank Balance £	11220	13550	15980	18410	22705	28815	34975

According to the above business model:

- The initial seed investment is expected to be gathered from private investors who will be offered 20% stake of the whole company; hence the investment is not needed to be returned.
- Development time required is estimated to be around 1 month, this is less because it is planned to import the complete devices with everything attached on printed circuit board, code is already in its final form.
- Few days (10-15) are needed for initial marketing.
- Breakeven is expected to be reached in month 2, after which the company will start earning profit.

Unique Selling Point:

The world in now more aware about potential viruses than ever and gradually the lockdown is being eased around the world which means more and more people will be visiting places of work, eateries and entertainment, there is no such device in the market, yet which can mark the attendance as well as take the temperature of the employee hence there is a huge potential is providing companies with this device.

4.0 EE4IOT ONLY – Deployment considerations

Scenario:

The device is to be installed at the entrance of a museum for the employees of that museum. Only the main entrance marked is to be used for the entry into the museum.

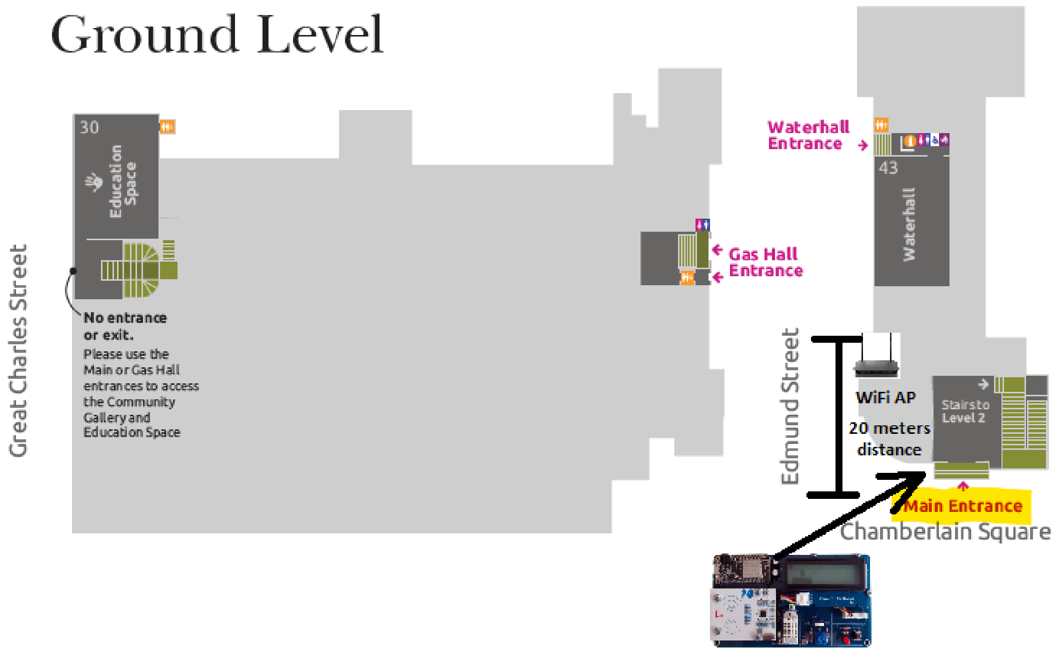

Figure 6 MAP of Museum

The proposed distance from the closest WiFi access point to the device is 20 meters, link budget can be calculated to verify the working feasibility if this device.

Table 5 Link budget

WiFI AP (Cisco WRP500) (802.11g)	ESP8266 (802.11g)
$P_{Receiver_{sensitivity}}$ = - 84 dBm [18]	$P_{Receiver_{sensitivity}} = -$ 75 dBm [21]
$P_{Transmitted}$ = +15.8 dBm [19]	$P_{Transmitted}$ = +17 dBm [21]
$Gain_{Receiver} = 2\ dBi$ [20]	$Gain_{Transmitter} = 2\ dBi$

$$Frequency = 2.4\ GHz \qquad Wavelength(\lambda) = \frac{3\times10^8}{2.4\times10^9} = 0.125\ m \qquad Distance = 20\ m$$

Power Received to Device from AP:

$$Receiver_{Sensitivity(ESP8266)} = \frac{10^{-\frac{75}{10}}}{1000} = 3.16\times10^{-11}\ Watts$$

$$Power_{Received(ESP8266)} = P_{T(\text{WiFI AP})}\cdot G_T\cdot G_R\cdot\left(\frac{\lambda}{4\pi d}\right)^2$$

$$Power_{Received(ESP8266)} = 3.12\times10^{-8}\ Watts$$

$$Power_{Received(ESP8266)} \gg Receiver_{Sensitivity(ESP8266)}$$

Power Received to AP from Device:

$$Receiver_{Sensitivity(AP)} = \frac{10^{-\frac{84}{10}}}{1000} = 3.98\times10^{-12}\ Watts$$

$$Power_{Received(AP)} = P_{T(\text{Device})}\cdot G_T\cdot G_R\cdot\left(\frac{\lambda}{4\pi d}\right)^2$$

$$Power_{Received(AP)} = 4.96\times10^{-8}\ Watts$$

$$Power_{Received(AP)} \gg Receiver_{Sensitivity(AP)}$$

For both AP and Device, the received power is well above the minimum required power hence there will be no problem in communication between the 2 devices.

Power consumption of the device:

Table 6 Power consumption of AntiSars

Component	Current Drawn (milli Amperes)
Microcontroller (ESP8266)	80 [21]
Temperature Sensor (MLX90614)	1.5 [22]
RFID reader (VMA405)	20 [23]
RGB LCD (Grove 16x2)	50 [24]
Total	151.5

$$Power = Voltage \ \times Current$$

$$Power = 3.3\,V \ \times 151.5 \ \times 10^{-3} A$$

$$Power \cong 0.5\,Watts$$

Cost of running the device per year:

Table 7 Running cost of AntiSars

Component	Current Drawn (milli Amperes)
Days in 1 year	365
Hours in a day	24
Energy consumption per day	0.5 X 24 = 0.012 KWh
Energy consumption per year	0.012 X 365 = 4.38 KWh
Cost of 1 KWh	0.172 **£**
Yearly cost of running device	0.172 X 4.38 = 0.75 **£**

Future proofing:

- Software updates will be done after every 6 months or earlier if necessary, by the design and installation engineer by visiting the site.
- HTTP will be replaced by HTTPS in future
- A separate dashboard will be designed just for the customer which will be password protect and only administration will be able to access the data using LAN only, this will make sure no one outside LAN gets access to the data

5.0 Conclusion

This device is still under development phase and there are many things which can be improved but still it is much better than all such existing devices since no feasibility study and commercial analysis such as this one has been done for them. AntiSars is the need of our present and future.

In future, HTTPS can be used instead of HTTP for more security, google firebase or google cloud paid account can be used instead of free MQTT brokers, that will make the device secure from many attacks.

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