

1708174

by Jordan Gough

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65-70

- ① RESEARCH WAS OK, BUT THE CITATION LIST WAS A BIT SHORT CONSIDERING THE POTENTIAL OF THIS ASSIGNMENT.
- ② KNOWLEDGE AND UNDERSTANDING WAS DEMONSTRATED, BUT YOU SHOULD HAVE CONTEXTUALISED THE ARGUMENT TO A SINGLE INDUSTRY - IE ENERGY/OIL.
- ③ THE REPORT WAS A BIT DESCRIPTIVE AND LACKED SOME CRITICAL ANALYSIS. AGAIN, A CONTEXT WOULD HAVE HELPED.
- ④ MORE EMPHASIS WAS NEEDED FOR SECURITY/PRIVACY AS THIS IS THE MORE CONTROVERSIAL ASPECT OF IOT.
- ⑤ THE WEATHER STATION WAS IMPLEMENTED SUCCESSFULLY.
- ⑥ SOME GOOD CONCLUSIONS.

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1. Executive Summary

This report identifies the Internet of Things as a concept and analyses how it began, how it is changing the modern world and how it needs to improve to remove or reduce security and privacy concerns.

The research conducted has confirmed that the initial use of the term was in 1999, referring to the use of the radio frequency identification tags. However, further investigation revealed that the idea of connecting devices to a network has been applied since the early 1980s. However, this was connecting a vending machine to a research network within a university, rather than over the internet. As the population has grown and technology has advanced, devices have achieved the ability to connect to the internet or cloud servers – with a large increase in the ratio between people and connected devices seen between 2008 and 2009, due to the release of devices such as smartphones and tablets. The issues generated through the use of connected devices were found to include cyber attacks and distribution of data amongst third parties, which can be combated through a variety of means such as the use of multiple networks or the implementation of additional device identification.

Is there a specific context?

Some of the researched ideas were applied to an Arduino weather station, which measures current weather conditions and displays them as real time or historical data through both a web browser and mobile dashboard. The device was placed in different conditions to ensure the functionality of the sensors. Although operational, the device should have further protection measures implemented, as found through the researched recommendations, to prevent unauthorised access.

2. Research

Haller, et al. define the Internet of Things (IoT) as “A world where physical objects are seamlessly integrated into the information network, and where the physical objects can become active participants in business processes. Services are available to interact with these “smart objects” over the Internet, query their state and any information associated with them, taking into account security and privacy issues.” (2008, p. 2)

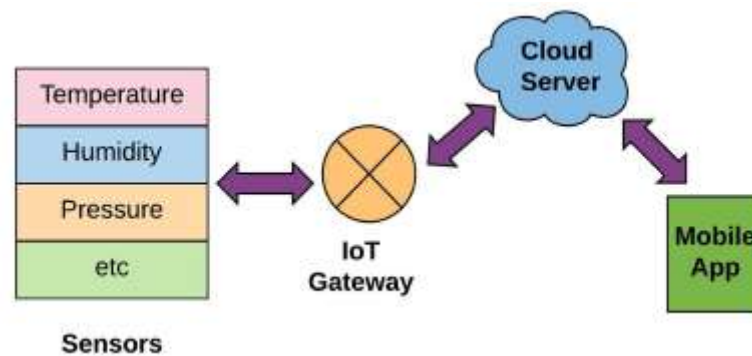


Figure 1 – Typical Network Architecture (Ramasamy & Kadry, 2021)

Although definitions vary, the IoT is the concept of connecting devices, which are embedded with electronics, software and web capabilities, to a network which allows these objects to gather and exchange information. The collected information is used to identify the status of the device. However, alternative data can be collected using a variety of devices and sensors and accessed using an application or dashboard. For example, using a smartphone to access a smart heating device in the home. The IoT is made up of four distinct layers:

- The Physical Layer – Made up of the general and sensing devices, which are gathering or receiving data. Sensing devices are used to measure parameters, such as temperature, whereas general devices include appliances that can use this data, such as an air conditioner. Additionally, the likes of routers and switches are required to connect the devices, and servers or storage devices can be used to process the data locally.
- The Network Layer – Consisting of the gateways, specifically the internet communication, used for data transmission and interconnection between multiple devices.
- The Cloud Layer – Where the collected data is processed and stored for analysis and management through the use of servers.
- The Application Layer – Containing the protocols used for device communication and provides a dashboard or portal used to access, display and use the data that has been collected.

(IoT Technology Working Group, 2018)

Despite not being a new concept, research and advancements into modern technology and market trends have made the IoT more popular, due to the ease of connecting devices together and to the internet. These trends include:

- Ubiquitous Connectivity – A high-speed network, which is always running, allowing for almost all types of device to be connected to the internet.
- Computing Economics – Providing superior computing power whilst reducing power consumption and cost.
- Advances in Data Analytics – The improvement of computing power, data storage and the cloud, alongside the development of new algorithms, allow for accumulation and analysis of large amounts of data.
- Widespread Adoption of IP-Based Networking – IP is the networking standard and is offering a platform of software and tools to implement into devices inexpensively.
- Miniaturisation – The advancements being made into manufacturing allow for the required communication technologies to be integrated into small devices which, in conjunction with computing economics, has led to the devices of both reduced size and cost being developed.
- The Rise of Cloud Computing – The introduction of cloud computing has granted small devices to process and store data, whilst networking with analytical and control capabilities.

(Rose, et al., 2015)

Although already prevalent, the transformative potential for IoT implementation across a variety of sectors and industries could be revolutionary for technological engagement. It adds an extra depth to an endless number of manufactured products that currently do not contain any internet connectivity but would stand to benefit from it. Recent examples include wearable devices, such as smart watches, which have led to a market growth amongst consumers, due to the additional health monitoring or communication features that are not offered by a normal watch. Alongside the possible manufacturing developments, the use of IoT technology can, to an extent, improve industries through other means, such as the use of lighting or heating sensors to reduce the mass use of electricity and save on costs. It can also improve industry applications via five key characteristics: Connecting, Collecting, Monitoring, Monetising and Optimising. For example, in the case of the energy sector, 'Connecting' would refer to the use of smart home monitoring devices, 'Collecting' would gather the power consumption data from a household and 'Monetising' would use the

collected data to improve investment into distribution. 'Monitoring' would improve data acquisition on otherwise unmonitorable equipment and 'Optimising' would identify any maintenance requirements of the equipment. (The Economist, 2020)

The initial coining of the term 'The Internet of Things' came from Kevin Ashton in 1999, during a presentation in which he suggested the use of radio frequency identification (RFID) tags to track cosmetic products throughout a supply chain, using the internet and without the need for human involvement. Although this was the first use of the term, there are previous examples of the IoT being implemented. (Hamza, 2022)

One example of an earlier innovation came in 1990. John Romkey wanted to prove that he could use the Simple Network Management Protocol (SNMP) to physically control an object, instead of its conventional use of managing routers and inspecting packets. Through the use of a low current relay and a SNMP code, a toaster was controlled using a computer's parallel port by lowering the bread into the machine and toasting until it reached its desired amount, before cutting the power. (Romkey, 2017)

However, the earliest known case is from the early 1980s. A vending machine at Carnegie Mellon University red indicator lights that illuminated briefly when a bottle was purchased from a particular column and remained illuminated when all of the bottles were gone. A group of students fitted a board to the machine which monitored the status of the lights multiple times per second and fed the information back to a departmental computer, through the use of the Advanced Research Projects Agency Network (ARPANET) – a predecessor to the modern internet. This system was used to track the stock levels of the machine and how cold the drinks were. (Teicher, 2018)

Cisco (2011) believe that the IoT was truly born during 2008 to 2009. This is based on the time at which the ratio of "connected devices" to people exceeded 1 – specifically 1.84 – caused by the introduction and demand of early smartphones and tablets – as seen in Figure 2. As more devices have gained connectivity, the ratio has increased to an estimated 6.5 devices per person – which should continue to rise as new technology is developed and more areas of the world acquire access to the internet.

A single context is 'the energy sector' rather than a collection of individual examples

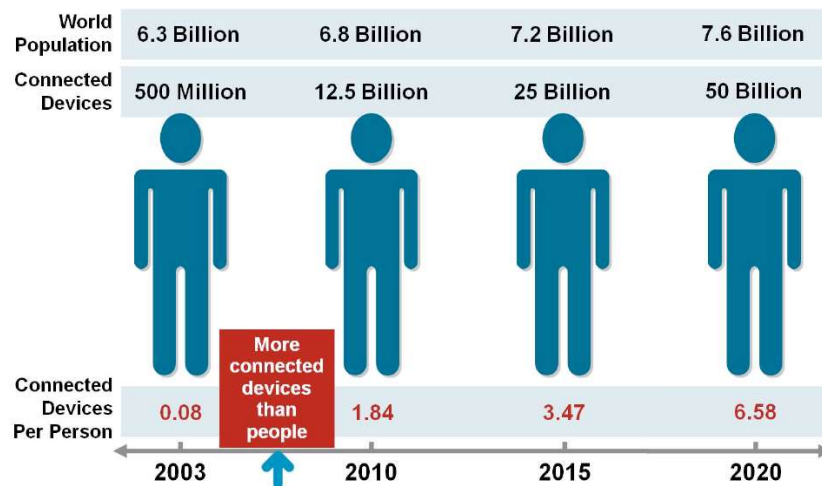


Figure 2 – Ratio of “Connected Devices” to People (*Evans, 2011*)

For devices to connect and talk to each other, four standard communication models are used for networking. The models are as follows:

1. Device-to-Device Communication
2. Device-to-Cloud Communication
3. Device-to-Gateway Communication
4. Back-end Data-sharing

Device-device communication refers to the connection of two or more devices, without the requirement of an intermediary server. They can connect over the internet or through the use of an IP network. However, they are not limited to internet connection and can use other methods, such as Bluetooth, or Z-wave and ZigBee which are low power radio frequencies. A common application for this model is household automation, using devices that exchange small amounts of data, including thermostats or light switches. However, the main issue that arises from this model is that some devices are not necessarily compatible with each other due to the difference in protocols and thus variety can be limited to certain families. For example, devices that use the ZigBee protocol are not compatible with those that use Z-wave, due to the difference between the radio frequencies used. (Rose, et al., 2015)

When using device-to-cloud communication, the device connects a cloud server with the main purpose of exchanging data. This is generally achieved using existing methods, including Wi-Fi and ethernet, to maintain communication between the device and the network. Again, this can be applied to home automation with some manufacturers applying this model to their devices. This allows the data, such as energy consumption, to be collected and analysed, whilst permitting the user to control devices from smart devices. A similar issue to device-to-device is present with this model, in that the cloud servers are

hosted by the manufacturers and thus limits the customer to alternatives, unless multiple different servers are used. (Rose, et al., 2015)

Device-to-gateway communication, or device-to-application layer gateway (ALG), allows an IoT device to connect to a cloud server indirectly, through the use of an ALG service. This typically means that there is a software application on a local device which acts as the mediator between the device and the cloud, whilst providing security and data conversion. The most common gateway device would be a smartphone or tablet, which is relaying the gathered information back to the cloud, via an app. For example, many smart watches have to connect to a smart phone, through a dedicated app, to access the cloud – thus preventing them from using the device-to-cloud model. (Rose, et al., 2015)

Back-end data-sharing is built upon the device-to-cloud model. However, this model gives the user, or permitter third parties, the ability to view a smart device's data from a cloud service alongside data provided by other sources. The data from all of the devices is uploaded into a "data silo" from one service provider – instead of individual silos. This could be applied to gathering energy usage information from multiple devices and collating it in one place to find the total consumption. (Rose, et al., 2015)

One of the main concerns for IoT devices are the potential security threats that they come under. Cyber-attacks, such as denial-of-service or ransomware, can be launched on the devices in an attempt to steal vital data from people or companies. In many cases, these attacks can go completely unnoticed by the user because of how sophisticated they can be but can also be difficult to diminish without the correct resources. The security threats that are present can even lead to bigger issues beyond the IoT devices, meaning that businesses must consider all methods of attack when producing high quality products for a consumer, at the expense of costs. However, there are things the users can do to protect their devices.

- By using a device identification tool, real-time connectivity data of devices and profiles on the network can be collected.
- Educating employees, admins or other users on the network about the importance of using strong network passwords. This allows the owners to control and limit devices or profiles connecting to the network, whilst restricting the movement of attackers.
- Having a distinct network available for IoT devices will block any attackers from using the smart devices as a route into the sensitive data stored on the primary

devices, which would be connected to the main network. Although possible, it would be difficult for an attacker to move between the networks.

- The implementation of a “honeypot” on a network provides a trap for attackers to fall into and be observed - as information about them is collected and analysed, giving the opportunity to pre-empt attacks, evaluate any malware and resolve the issue.

(Dell Technologies, Inc. , 2021)

Privacy issues during the collection, storage and processing of sensitive data are another concern of using connected devices. As per the General Data Protection Regulation (GDPR), users can decide what information can be collected – which applies to all application development, including IoT devices. The applications developed should provide a means of viewing and modifying the data as a user. Alongside this, the identities of the user should be kept anonymous and untraceable. Updates to the legislation imposed by the GDPR include ensuring that companies are only collecting necessary data for the desired purpose, the information being collected is kept up-to-date and the reason for collecting is legitimate. In the event that the legislation is not followed, the applications or devices may be prohibited by law. (Jurcut, et al., 2020)

In many cases, there is a possibility that a device is collecting data and distributing it amongst third parties, without the user being aware. This is typically done through voice controlled devices which can continuously listen and personalise how the data is used – such as using targeted adverts, which can sometimes be beneficial. However, users could potentially lose faith with the internet, amid privacy concerns, should they become aware of the third party influence. Additionally, collected information used by third parties, in combination with other collected data, can slowly destroy the anonymity of users on the internet as more is revealed about them and their lifestyles. (Rose, et al., 2015)

3. Methodology, Testing and Results

To develop a continuous monitoring weather station, an “Arduino Opla IoT Kit” was used. The kit was assembled by mounting the “MKR WiFi 1010” board on top of the “MKR IoT Carrier” and placing it inside the protective casing. Once assembled, the device was connected to a PC using a USB cable – which also provided power to the device. Through the Opla website’s “IoT Cloud” page, the kit was configured as a “thing”. This provided the opportunity to name the device, connect it to a wireless network and determine the variables that the device will be measuring. The device was suitably named “Weather Report” and five variables were chosen – these being humidity, light, pressure, temperature and weather_report. The light variable was set-up as an integer, the weather_report as a string and the remaining variables as floating points.

The screenshot displays the Things IoT Cloud interface. At the top, there's a 'Things' header with a bell icon and a 'CREATE THING' button. Below this is a filter dropdown set to 'All device types'. A table lists devices, with 'Weather Report' selected. The device details for 'College' (Arduino MKR WiFi 1010) are shown. The 'Variables' section lists five variables: Humidity (float), Light (int), Pressure (float), Temperature (float), and Weather_report (String). The 'Device' section shows the device name 'College', its ID, type, and status (Offline). The 'Network' section shows the Wi-Fi name and password.

Name ↓	Device	Variables	Last Modified
☐ Weather Report	College Arduino MKR WiFi 1010	Weather_report +4	08 Apr 2022 15:32:12

Variables		
Name ↓	Last Value	Last Update
☐ Humidity float humidity;	50.721	09 Apr 2022 14:33:23
☐ Light int light;	2	09 Apr 2022 14:33:23
☐ Pressure float pressure;	101.531	09 Apr 2022 14:33:23
☐ Temperature float temperature;	9.106	09 Apr 2022 14:33:23
☐ Weather_report String weather_report;	It is dark outside	09 Apr 2022 14:33:17

Device
 College
ID: 89500590-a8fd-41ed-9051-...
Type: Arduino MKR WiFi 1010
Status: Offline
Change Detach

Network
Wi-Fi Name: BTWhol...
Password: *****
Change

Figure 3 – Device Configuration

By switching to the “Web Editor” page, the code for the device could be written, verified and uploaded to the device. The code, which can be found within the appendix, features the variables and the units they will utilise, the text that will be displayed on the weather report, functionality for the capacitive buttons and design customisation, such as text and background colours. The weather report variable is comprised of six “if” statements and

produces a report based on comparisons between variables. This webpage also features a “monitor” tab, which ensures that the device is connected to the network.

Returning to the “IoT Cloud” page, a dashboard was designed to view the variables that were created. Initially, the dashboard was set up using ‘widgets’ for real-time monitoring of the conditions specified and a text-based weather report, but was later modified to include graphs showing how the conditions are currently changing or how they have changed over a selected time interval – be it an hour, a day, a week or 15 days. The pressure, in kilopascals, and light, in lux, were both displayed as integer values, the humidity as a percentage and the temperature as a gauge with a range -10°C to 100°C. The dashboard was arranged so that the graphs were placed next to the live measured variables.

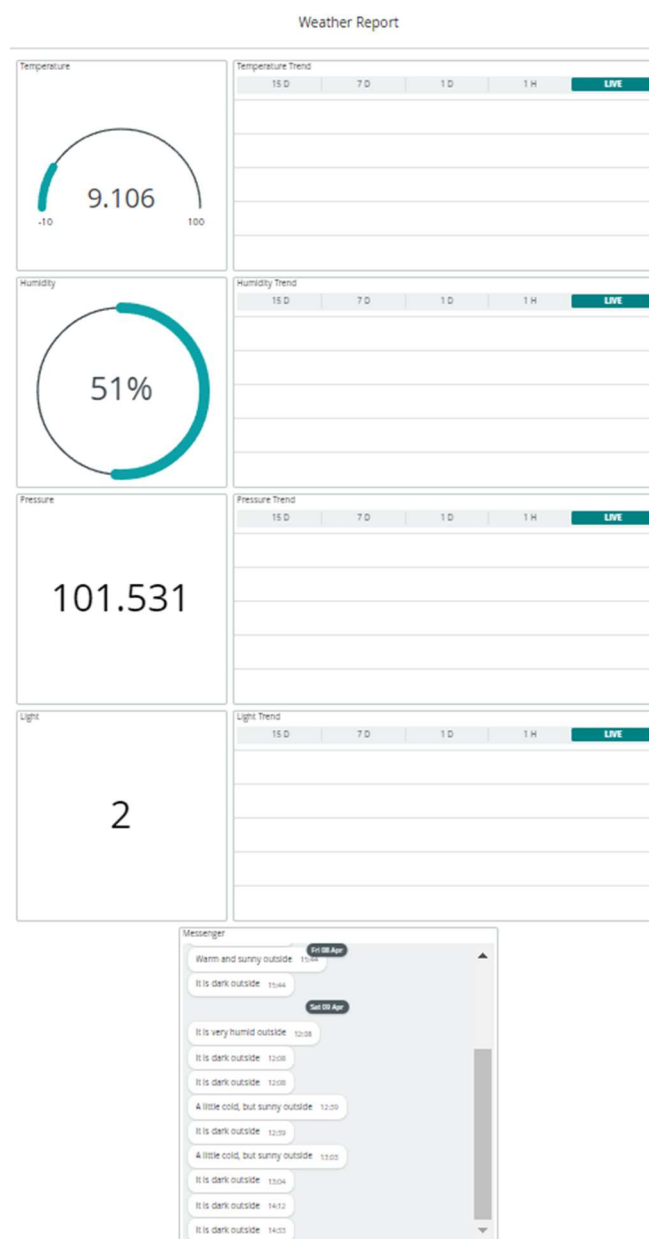


Figure 4 – Web-based Dashboard

Along with the web dashboard, a mobile dashboard was created to monitor the same conditions through the “Arduino IoT Cloud Remote” application on a smartphone or tablet. Although the measured values could be seen on the mobile and web dashboards, testing was required to ensure that they would respond to the changes in their surrounding conditions. The measured temperature at start-up was roughly 20°C and the light was measured at 43 lx – or lm/m^2 . The pressure value of 101kPa is absolute pressure and the humidity of 60% is at the top end of the ideal relative humidity.



Figure 5 – Initial Start-up Measurements

Due to the difficulties in influencing the humidity and pressure, the temperature and light sensors were tested by placing the weather station inside a refrigerator. Immediately upon closing the door, the light reading dropped to 0 due to the internal light switching off. The temperature began to drop, but it took a long period of time to drop – reaching 9°C before the device was removed. The screenshots of the dashboard below, taken after the device’s removal, show the history of both variables. It can be seen that the temperature dropped over the same time period that the light was low. However, there are spikes present in the lighting graph which indicate the door being opened.

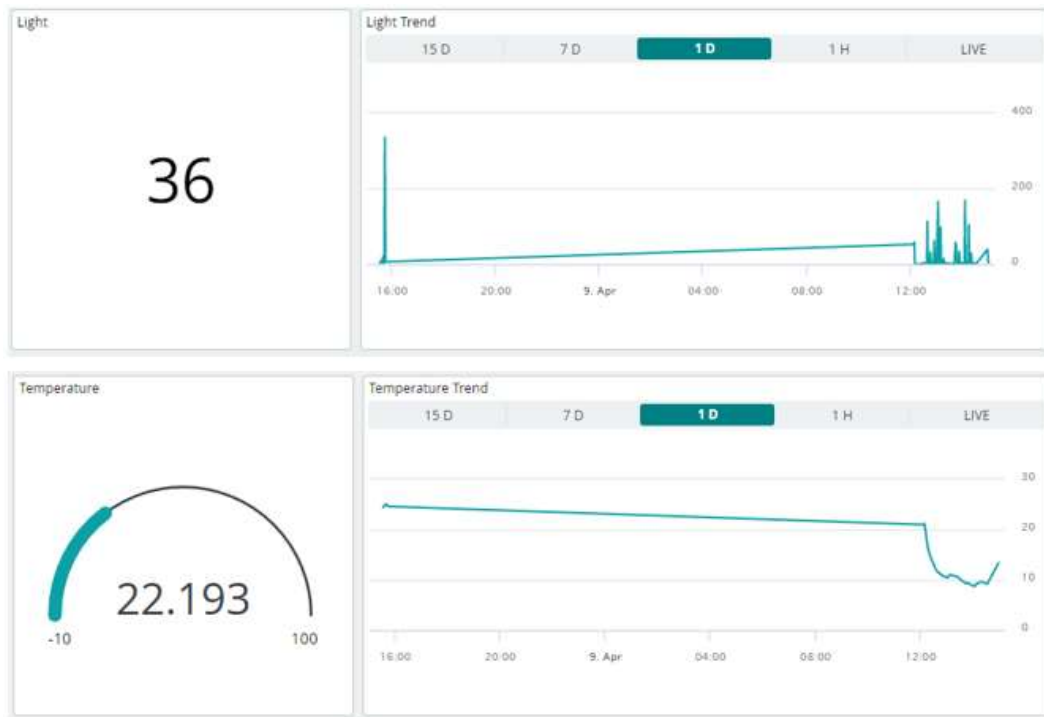


Figure 6 – Weather Station Refrigerator Test (Web Dashboard)

The changes were also identified on the app, indicating that the mobile dashboard was correctly configured.

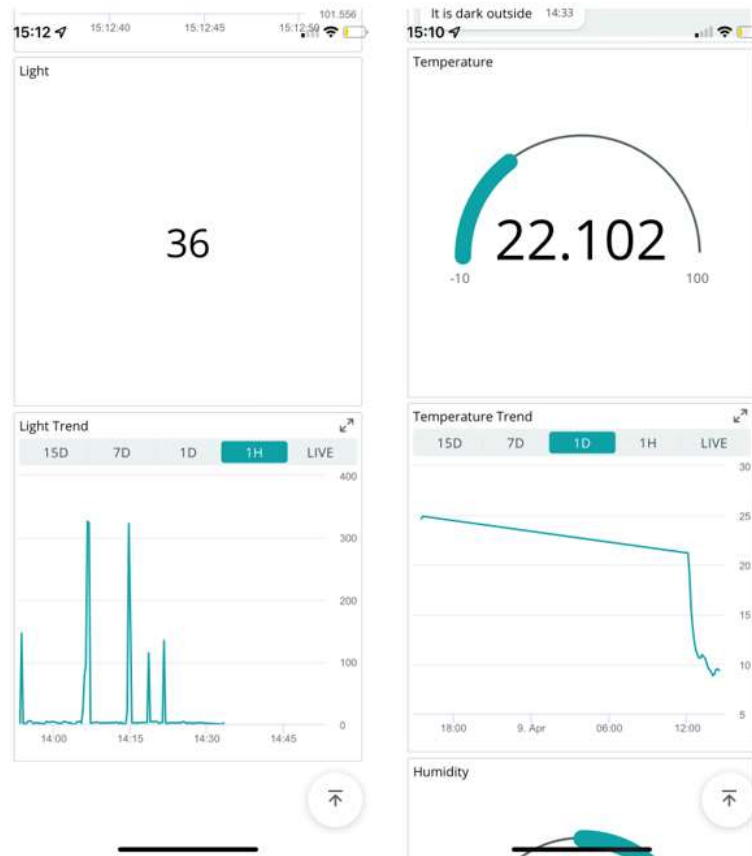


Figure 7 – Weather Station Refrigerator Test (Mobile Dashboard)

The weather report variable was designed to only report when it noticed a condition change, rather than the 1 second interval set on the other variables. Therefore, the opening and closing of the door, triggering the light, would have been enough of a noticeable change to create a report. This can be seen below, where the report changes between “It is dark outside” and “A little cold, but sunny outside”.

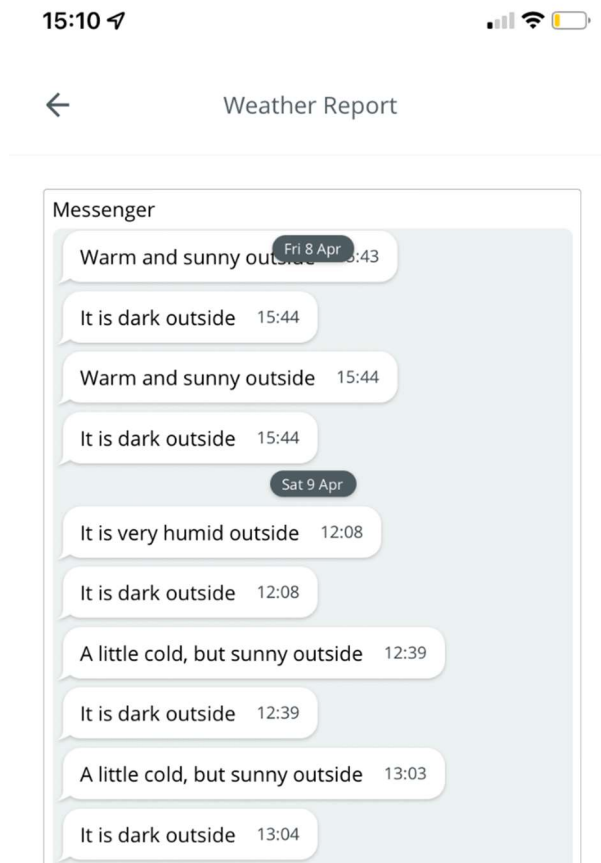


Figure 8 – Weather Report (Mobile Dashboard)

An additional test was conducted on the light sensor, to ensure the value would increase. This was done by the use of a torch, to put direct light onto the sensor. In this case, the light reading increased to 1410 lx – 33 times the reading when it was not influenced.



Figure 9 – Light Sensor Torch Test

4. Conclusions

A variety of sources were researched to gather information regarding the Internet of Things and form an understanding into the different aspects of the concept. The main focus areas of the research included the origins of the IoT, the communication models used by devices and networks and the challenges that the idea faces - from both security and privacy standpoints.

A continuous monitoring weather station was designed and created, through the use of an Arduino Opla IoT kit. This station was set-up using the web editor and IoT cloud, located on the Arduino Opla website. This set-up included entering the network details for the device to access the cloud, selecting the desired variables that the kit would be using, importing the code and designing a dashboard for both a web browser and a mobile application. Four of the five variables selected were the conditions that were being monitored – light, humidity, temperature and pressure – whereas the remaining variable was the weather report. The code included information, such as the measurement units used, and featured customisation options to make the local display different for each variable.

The dashboards were designed with both live and historical monitoring under consideration – using both numerical displays, such as gauges and percentages, and graphs. This meant that the device could be left running throughout the day and the conditions could either be checked periodically for a current weather, or later in the daytime to see how they have changed.

The weather station's functionality was evaluated by placing it inside a refrigerator. This allowed drastic changes to be noted on both the temperature and light readings, given it was both cold and dark inside. The temperature was seen as decreasing gradually on the graph, while the light reading dropped instantly. This showed that the temperature sensor was not affected by sudden, large temperature changes. An additional test was conducted by shining a torch onto the light sensor. Both the humidity and pressure sensors were limited in testing options.

Only four variables are being monitored currently, but this could be expanded with extra sensors and code to include additional conditions such as UV radiation or moisture. The dashboard and web editor are both accessed through the same website, which is locked behind a user account with a password. This means that there is limited protection on the device and, referring back to the research completed, further verification measures could be implemented to protect the device from being activated. This could include the use of two-

factor authentication for logging in and using the web browser account to approve additional devices that are wanting to access the dashboard.

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6. Appendix

```
1  /*
2   Sketch generated by the Arduino IoT Cloud Thing "Untitled"
3   https://create.arduino.cc/cloud/things/151ec4be-5c5f-47b2-9225-e383f85732e5
4
5   Arduino IoT Cloud Variables description
6
7   The following variables are automatically generated and updated when changes are made to the Thing
8
9   float humidity;
10  float temperature;
11  int light;
12  float pressure;
13  String weather_report;
14
15  Variables which are marked as READ/WRITE in the Cloud Thing will also have functions
16  which are called when their values are changed from the Dashboard.
17  These functions are generated with the Thing and added at the end of this sketch.
18  */
19
20  #include "thingProperties.h"
21  #include <Arduino_MKRIoTCarrier.h>
22  MKRIoTCarrier carrier;
23
24  int modeSelect = 0;
25  int previousMode = 0;
26  int refreshCount = 0;
27
28  void setup() {
29    // Initialize serial and wait for port to open:
30    Serial.begin(9600);
31    //while (!Serial);
32
33    // Defined in thingProperties.h
34    initProperties();
35
36    // Connect to Arduino IoT Cloud
37    ArduinoCloud.begin(ArduinoIoTPreferredConnection);
38    //Get Cloud Info/errors , 0 (only errors) up to 4
39    setDebugMessageLevel(2);
40    ArduinoCloud.printDebugInfo();
41
42    //Wait to get cloud connection to init the carrier
43    while (ArduinoCloud.connected() != 1) {
44      ArduinoCloud.update();
45      delay(500);
46    }
47    delay(500);
48    CARRIER_CASE = true;
49    carrier.begin();
50    carrier.display.setRotation(0);
51    carrier.display.fillScreen(ST77XX_BLACK);
52    carrier.display.setTextColor(ST77XX_WHITE);
53    carrier.display.setTextSize(3);
54
55    carrier.display.setCursor(60, 80);
56    carrier.display.print("Weather");
57    carrier.display.setCursor(60, 120);
58    carrier.display.print("Station");
59    delay(2000);
60    carrier.display.fillScreen(ST77XX_BLACK);
61    carrier.display.setTextColor(ST77XX_WHITE);
62    carrier.display.setTextSize(2);
63
64    carrier.display.setCursor(70, 80);
65    carrier.display.print("Connected");
66    carrier.display.setCursor(50, 110);
67    carrier.display.print("To IoT Cloud");
68    delay(2000);
69  }
70
71  void loop() {
72    ArduinoCloud.update();
73    carrier.Buttons.update();
74
75    while(!carrier.Light.colorAvailable()) {
76      delay(5);
77    }
78  }
```

Figure 10 – Weather Report Code - Part 1

```

77 }
78 int none;
79 carrier.Light.readColor(none, none, none, light);
80
81 temperature = carrier.Env.readTemperature();
82 humidity = carrier.Env.readHumidity();
83 pressure = carrier.Pressure.readPressure();
84
85 if(carrier.Button0.onTouchDown()) {
86     modeSelect = 0;
87 }
88 else if(carrier.Button1.onTouchDown()) {
89     modeSelect = 1;
90 }
91 else if(carrier.Button2.onTouchDown()) {
92     modeSelect = 2;
93 }
94 else if(carrier.Button3.onTouchDown()) {
95     modeSelect = 3;
96 }
97 else if(carrier.Button4.onTouchDown()) {
98     modeSelect = 4;
99 }
100
101 if(modeSelect != previousMode) {
102     updateDisplay();
103     previousMode = modeSelect;
104     refreshCount = 0;
105 }
106 else if (refreshCount >= 50) {
107     updateDisplay();
108     refreshCount = 0;
109 }
110
111 if (humidity >= 60 && temperature >= 15) {
112     weather_report = "It is very humid outside";
113 }
114 else if (temperature >= 25 && light >= 700) {
115     weather_report = "Hot and sunny outside";
116 }
117 else if (light <= 100) {
118     weather_report = "It is dark outside";
119 }
120 else if (temperature >= 15 && light >= 700) {
121     weather_report = "Warm and sunny outside";
122 }
123 else if (temperature <= 10 && light >= 700) {
124     weather_report = "A little cold, but sunny outside";
125 }
126 else if (humidity >= 90 && temperature <= 15) {
127     weather_report = "It is wet and rainy outside";
128 }
129 refreshCount++;
130 }
131
132 void updateDisplay () {
133     if (modeSelect == 0) {
134         carrier.display.fillScreen(ST77XX_RED); //screen colour
135         carrier.display.setTextColor(ST77XX_WHITE); //text colour
136         carrier.display.setTextSize(4);
137
138         carrier.display.setCursor(70, 50);
139         carrier.display.print("Temp:");
140         carrier.display.setCursor(40, 110);
141         carrier.display.print(temperature);
142         carrier.display.print(" C");
143     }
144     else if (modeSelect == 1) {
145         carrier.display.fillScreen(ST77XX_BLUE); //screen colour
146         carrier.display.setTextColor(ST77XX_WHITE); //text colour
147         carrier.display.setTextSize(4);
148
149         carrier.display.setCursor(70, 50);
150         carrier.display.print("Humi:");
151         carrier.display.setCursor(40, 110);
152         carrier.display.print(humidity);
153         carrier.display.print(" %");

```

Figure 11 – Weather Report Code - Part 2

```

154 }
155 else if (modeSelect == 2) {
156     carrier.display.fillScreen(ST77XX_GREEN); //screen colour
157     carrier.display.setTextColor(ST77XX_BLACK); //text colour
158     carrier.display.setTextSize(4);
159
160     carrier.display.setCursor(60, 60);
161     carrier.display.print("Light:");
162     carrier.display.setCursor(80, 120);
163     carrier.display.print(light);
164 }
165 else if (modeSelect == 3) {
166     carrier.display.fillScreen(ST77XX_CYAN); //screen colour
167     carrier.display.setTextColor(ST77XX_BLACK); //text colour
168     carrier.display.setTextSize(4);
169
170     carrier.display.setCursor(60, 60);
171     carrier.display.print("Press:");
172     carrier.display.setCursor(20, 110);
173     carrier.display.print(pressure);
174     carrier.display.print("kPa");
175 }
176 else {
177     carrier.display.fillScreen(ST77XX_BLACK);
178 }
179 }

```

Figure 12 – Weather Report Code - Part 3

FINAL GRADE

GENERAL COMMENTS

Instructor

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GRADING FORM: CSG-RUBIC

JORDAN GOUGH**0****RESEARCH-INFORMED LITERATURE**



There was evidence of further reading and research with the inclusion of a reference list and appropriate in text referencing. Your interpretation and understanding of the additional research was good. Your references were appropriate to the task and your reference list was of an appropriate length for this assignment. You should consider widening your range of sources for future assignments.

11/20**KNOWLEDGE AND UNDERSTANDING**



The knowledge and understanding of the subject demonstrated by this assignment was reasonably extensive. There were very few gaps in your knowledge of the basic principles and your understanding of the higher level concepts was demonstrated to a limited degree. You have

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demonstrated some critical understanding of the main concepts and expanded your knowledge beyond that contained in the course notes, however your explanations need to be more detailed and written with a greater emphasis on critical evaluation rather than description.

ANALYSIS



Your analysis of the task was generally very good, both in class and as shown in this assignment. You have demonstrated sound critical analysis skills and your approach to the task was logical. You carried out a detailed evaluation of the results and included a good conclusion relating the practical results to researched theory. The conclusions demonstrated very good cognitive skills and the ability to interpret quantitative and qualitative data without error.

17/30

PRACTICAL APPLICATION AND DEP.



Your application of practical skills for this task was generally excellent. You used both the basic and advanced features of the resources appropriately when designing the circuit and you used appropriate advanced options for testing and evaluating the circuit performance. You managed to design an effective circuit that functioned well within the specification and achieved this by rarely asking for assistance thus demonstrating some advanced problem solving skills.

9/10

SKILLS FOR PROFESSIONAL PRAC.



Your written report was generally well written in a coherent and fluent manner that contained most of the required detail, although it lacked the depth of explanation required in places. You need to be more selective with where you put diagrams and graphs, only put those essential for the explanation in the report, the rest can be referred to in the appendix.

6/10