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| **Implementing improved methods of Patient care using IoT, Mobile Devices and Website Applications**  Aaron Stones  BSc Computing with Honours, 2020 |

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| School of Design and Informatics  Abertay University |

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# Table of Tables

# Acknowledgements

# Abstract

300 words

Usually read first by the reader

Write this last

Summarise what you did, results and conclusions

Not an intro so no references

# Abbreviations, Symbols and Notation

If required

# Chapter 1 – Introduction

**750 – 800 words + 133 words per section**

**Set the scene**

**Background to and purpose of the investigation**

**Scope**

**Project aims/research questions**

**Likely to be more focussed than the proposal**

**End with an overview of the remaining chapters**

Within the United Kingdom right now it is estimated that around 410,000 people live inside ‘Care Homes’ (GOV.UK, 2019). Around 10% of these residents have primary health options, this means the patient is no longer able to look after themselves and have been admitted to residential care to protect them. A following 49% of the residents in ‘Care Homes’ are LA-funded, this is a scheme setup by the United Kingdom government to contribute to a quarter of the living costs for these residents (GOV.UK, 2019).

However, it has been reported within the media recently that due to an ever increasing and ageing population, a need for patients to be admitted due to concerns for their health (primary options) out-ways the need for these forms of care. This is in comparison to residents on LA-funded schemes, who could achieve an equally adequate or even better form of care from their own homes through the use of technology. This technology could be used to manage the different conditions patients may have or used to detect these conditions early.

Within these ‘Care Homes’ many patients are living with both; early and advanced neurological brain conditions and require regular assessment from Nurses and Doctors to assess the progression of their disease and any notable changes. This only happens if a patient has been correctly diagnosed. If Parkinson’s is taken as an example according to WebMD – “It has been estimated that, especially in its early stages, nearly 40% of people with Parkinson’s Disease may not be diagnosed, and as many as 25% are misdiagnosed.” (WebMD, 2019) This shows a lack of ability to accurately detect this conditions and so accurate care cannot be provided. The main means for the detection of degrading neurological conditions is the use of CT scans, which are both time consuming and expensive to public bodies like the NHS (National Health Service), with each scan costing around 609.70 pounds according to costevaluation.com (Costevaluation.com, 2019). This is a necessity to accurately detect neurological conditions but are in high demand. Mobile Phones and IoT devices could be used to run small tests before hand by the suspected sufferers to give an early prognosis of these conditions where then the CT scan is only a formality to confirm what is already known.

# Chapter 2 – Literature Review

## 2.1 Introduction

This chapter will investigate the work that has been proposed already to help ensure effective care is given to patients, and new forms of technology that could be used to help manage the effective care given to patients. There have been many studies into the way in which readings have are taken from patients and how these readings are; stored, processed, analysed and displayed to medical professionals. Many of the methods that are used to collect data from patients have not been updated for decades. During the reading takings, a lot of the process involves a lot of medical professional’s time in taking said readings. Many of these are simple readings such as; Heart Rate, Temperature, Weight, Blood Pressure. Most of the readings can be taken through new technologies such as smart phones and internet of things devices. Especially smart phones, which have vast arrays of sensors built into them can take a plentiful supply of readings from a patient without the need of a medical professional to be present, in the taking of these readings. These tests could be extended and upgraded to provide extra care for patients suffering with degenerative mental health conditions, through the use of the previously mentioned sensors within IoT devices and smart phones.

## 2.2 NHS and Data Collection

As previously mentioned, to monitor a patient’s health, basic readings are taken like; Heart Rate, Temperature, Weight, Blood Pressure. To take these readings, a patient is either required to visit their local hospital for an appointment with a Nurse/Doctor, or if they are incapable due to disability or old age, a District Nurse would be sent out to retrieve the readings. Possibly, a patient could wait for hours for these simple readings to be taken and for advice to be given to the patient. To take this further, a patient suffering with Parkinson’s a disease with no cure and very little ways to manage the disease. After a patient has been diagnosed with the disease they are taken for monthly assessments with a Doctor or specialised Nurse, where their tremors are visually looked at and the patient is asked if they have any concerns. At this point the appointment is complete and the patient is sent home with an action plan and appointment for the next month. According to the Patient website, a person with the Parkinson’s disease should receive; Parkinson's disease nurse specialists, Physiotherapy and physical activity, Occupational therapy, Speech and language therapy and Nutritional support (Tidy, 2020). Within the United Kingdom due to shortages within the NHS, the sheer amount of recommended care for a single patient cannot be provided to every sufferer of Parkinson’s. This means that only a Doctor’s appointment or a specialised Nurse will see a patient each month, they will report of whether further action is needed or if the patient is fine. If a patient requires an extra appointment for any reason, they are required to visit their local General Practitioner.

The vast care needed for patients with Parkinson’s cannot be provided within the United Kingdom, as previously stated, which means there is a need for change in which the way the disease is managed and other diseases are managed. This would allow for resources to be freed up to allow patients to get the care that they need and deserve. Also, what is needed is for the amount of data that we are collecting from patients to be increased to give a better understanding of how a patient’s condition is either degrading or improving. This would also prevent unnecessary hospitalisations because a more comprehensive view of a patient’s health has been gathered and a better understanding of their health has been gained. Within the clinical investigation ‘Residents: Frequency, Causes, and Costs’ it is suggested that the unnecessary hospitalisation of patients is likely to cause their health more issues due to the stress of being transferred to a hospital. The study then goes onto state that 67% of hospitalisations are avoidable and take up a great deal of NHS resources. These resources could be better utilised if it is found out that a patient did not need hospitalised. This also works if the patient takes a reading that a medical professional does not like and a life is saved because they were hospitalised with a serious condition.

## 2.3 IoT (in general)

Devices that have been previously mentioned can take lots of readings and send them to a server. One of these are IoT devices, or internet of things devices, these are small micro-computers that transfer data over a network to a cloud server without the need for Human-Computer or Computer-Human interaction. They carry a relatively low amount of processing power, RAM etc and are mainly used for the sending of said data. The fact they have low system performance means that they are very inexpensive pieces of technology and are simple to setup and utilise. Within the United Kingdom they have been used for devices like the Nest Thermostat, Berennis Smart Light Bulb, Sense Energy Monitor etc (Mishra, 2020). These devices have the ability to send and receive data from a server, the server usually acts on data based upon a user entering an input or a sudden change in the data being received by the server. These devices (as can be seen from the previous examples) can be programmed and have sensors added to them to provide different functionality for the user and send different kinds of data to a server. If this technology is applied in a medical sense, the NHS has put IoT devices through a rigorous testing phase. “As part of an initiative to set up testbeds to pilot new technologies in the health service, NHS England and the Department of Health has awarded £10m in funding to two 'test bed' projects that it describes as "IoT-led".” (Best, 2020). One of these projects is called, TIHM or Technology Integrated Health Management. This system is used to monitor patients with Dementia, reduce the need for hospital admissions and relieve the stress on carers (Sabp.nhs.uk. (2020)). The devices used are IoT devices, they send a signal to clinicians when they detect an issue with the patient such as; falls, turning on things they shouldn’t and long-term periods of idleness.

## 2.4 Something about mobile applications and their benefit

A further device that has been previously mentioned with a vast quantity of highly sensitive sensors, are Mobile Phones. These have the advantage over IoT devices, that they are widely used and the majority of the U.K population has a mobile phone. Most Smart Phones within the U.K have the ability to communicate with a web server from almost everywhere with the use of Mobile Data and Wi-Fi in most U.K homes, this allows for convenience when a User is needing to send or receive data from a server. Receiving data anywhere a User is, allows them to keep them up to date with any changes within the server, due to new data being entered or data needing to be entered. Examples of this have been used within rural countries within Africa, the technology is called tele diagnosis and it is used for patients to communicate with Doctors by sending them photos, information etc about their ailments and a Doctor will send different courses of action or treatments. The technology has been widely successful due to the instantaneous nature of Mobile Phones and the quality of the cameras, microphones etc to help a medical professional make an informed decision on the best course of action. As previously mentioned, the quality of the sensors within mobile phones are incredibly sensitive and can detect the smallest changes in movement, heat etc. sensors have been increasing in quality since 2014. GPS or Global Positioning System also allows people to pin point their locations and track their movements, whether that be for fitness, or for their own personal safety etc. GPS has been used to track elderly people with degenerative brain conditions such as Dementia to plot a circle as to an area where they are meant to be. If a Dementia sufferer travels outside of the circle set out by a program, a signal is sent to a server and a next of kin, carer or medical professional are contacted to check on the safety of the patient. This means if a Dementia sufferer gets confused and lost, the carer is able to locate them and bring them back home. Many Mobile Applications communicate between a server, the same server allows for communications from a web app. This could be to; manage data entered into the Mobile Application, User data or content within the application etc. They also provide a failsafe if a User forgets any of their login data.

## 2.5 Summary

# Chapter 3 – Methodology

Within this Methodology chapter, an explanation of the processes involved in the development of this project will be given. As well as, the justification for these processes. Techniques such as System Diagrams, Test-Driven Development, Surveys and qualitative Interviews will be discussed to show exactly how this project was birthed. The project followed a somewhat Waterfall development process, following the classic; Analysis, Design, Implementation, Testing and Evaluation steps. However, the way in which changes and suggestions were implemented have been handled in an Agile format. This allowed the developer to cope with these changes easier and track the progress of the project with greater ease.

## 3.1 Project Overview

In Lehman’s terms, this project will look to build a system that tracks different health measures of a patient. These measurements include; heart rate, blood pressure, body mass and patient temperature. These measures will be coupled with the hand shaking test developed as well. These measures will be sent to a server where they will be stored and presented to medical professionals in graphical format, this will allow the medical professionals to gain a better idea of patient degradation or improvement. The readings will be taken by sensors on a mobile phone, such as the accelerometer for measuring the intensity of handshakes, for patients with Parkinson’s. A simple memory game to plot a value for the patient’s well being in terms of the detection and monitoring of Dementia. These will all be done on a mobile phone. Not everyone in the United Kingdom ha a mobile phone, so an IoT device will be setup and use a health kit to take simple measurements (this device will not be able to conduct the Dementia or Parkinson’s measurements). The medical professionals will take all of the data that has been posted to the server and allow medical professionals to select patients and see their results, while communicating advice to patients and send messages/advice to individual patients.

## 3.2 Analysis

As Initially stated, the first stage undertaken was an analysis of the subject. This involved; a meeting with the subject specialist to see if the project idea was feasible, the creation of Aims & Objectives, the production of Software Requirements and an analysis of the requirements of each piece of software.

### Aims & Objectives

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| **Aim** | **Objectives** |
| Analyse the methods of which detection of incurable neurological disorders are carried out to utilise IoT and Mobile Devices, so a system can be developed that can be analyse and decide the best courses of action. | * Identify through interviews and research with medical professionals and literature what tests are used within the medical world to diagnose these issues. * Identify the methods used by medical professionals to monitor the progress of the disorder and provide effective care, to see if these can be or already have been digitised, and if so, can they be made more effective. * Analyse the data that has been collected, to develop a system to show graphs patients state either; bettering, deteriorating or stabilising. |
| Design an effective management system that incorporates all three technologies (Web App, Android Application and IoT device). | * Identify the system logic through the creation of a System Diagram. * Depict how the user data will be stored within the server through the creation of a Database Schematic * Create a diagram to show how each technology will be interconnected throughout the system. |
| Develop a system to manage the patients effectively through the use of the three technologies. | * Review and select the best methods for measuring a patient’s vital signs on both IoT and Android Devices. * Replicate the systems in place where possible and create new Algorithms where none exist. * Analyse the best free to use Application Programming Interfaces to display a patient’s results in graphical format. |
| Analyse the effectiveness of the system as a whole and the communication between integral parts. | * Conduct System Testing to make sure the system as a whole works effectively. * Conduct Unit Testing between the server and three devices, this will depict whether communication is effective or not. |
| Create an effective test plan to ensure the system is operating as planned. Test plan must incorporate an ability to measure accessibility as this system is for Elderly patients. | * Follow Test-Driven development to ensure code is secure and best practices are followed. * Unit testing will be conducted on functions to ensure functions and components are working as expected. * Accessibility testing must be conducted to ensure the system can be used by all patients. |
| Test the effectiveness of the measurements taken on both IoT and Android Devices, also how the results are presented within the web app. | * Analyse the results based on the developer’s vital signs taken with reliable medical instruments. * Compare different graph API’s to select one with a line of best fit and that us free to use. |
| Evaluate the hypothesis of the project through the use of Interviews and Surveys with medical professionals and the public. | * Assess the test subjects’ thoughts and opinions on the software using unstructured interviews. * Construct a following structured interview to gain data pertinent to evaluating solely the hypothesis. |

These Aims & Objectives have been set out to provide a clear direction of the project. They have also provided the basis for the development of the Functional and Non-Functional Requirements and will form the basis of testing to ensure either the aims and objectives have been met or have not.

### Functional & Non-Functional Requirements

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| Functional Requirements | |
| FREQ ID | Requirement |
| FREQ001 | Users must be able to register an account |
| FREQ002 | Users must be able to login to an existing account |
| FREQ003 | Users must be able to view their account information |
| FREQ004 | Users must be able to modify their account information |
| FREQ005 | Users must be able to easily contact their Doctor |
| FREQ006 | Users must be able to perform a test on a mobile and an IoT device |
| FREQ007 | Users must be able to delete their accounts and remove all their data from the Database |
| FREQ008 | The user must have an option to enter in readings manually that cannot be taken off a phone or IoT device |
| FREQ009 | Users must be able to contact support |
| FREQ010 | Users must have a way of displaying readings in graphical format for review |
| FREQ011 | Users must be able to receive advice form all medical professionals based on their conditions |
| FREQ012 |  |
| Non-Functional Requirements | |
| NFREQ ID | Requirement |
| NFREQ001 | This application will be responsive, and users will therefore be able to operate it with ease on multiple types of devices including mobiles, tablets and computers. |
| NFREQ002 | This application will be reliable, this will allow users to operate it with a high degree of trust, knowing that it will work as they expect it to. |
| NFREQ003 | This application will be scalable as it will accommodate heavier loads and large number of users |
| NFREQ004 | This application will be maintainable by the developers, and any other teams that work on it due to its thorough documentation. |
| NFREQ005 | This application will use secure practices, as it will be fully compliant with the Data Protection Act, meaning we will store the data securely and for the correct amount of time. The team will comply with the General Data Protection Regulation. |
| NFREQ006 | This application will be user-friendly and accessible where possible to allow for those with disabilities to use the application to its full potential. |

As well as Functional & Non-Functional Requirements, Many rules, regulations and standards must be followed throughout the development process. Some of these, have been set out by the I.E.E.E (Institute of Electrical and Electronics Engineers) or I.S.O (International Organisation for Standardisation). There are plenty of regulations set out by these organisations that the project team will be following these throughout the development phase. (www.tutorialspoint.com, 2018)

There are two main Laws that the developer will respect and avoid breaking at all costs the first one is the Computer Misuse Act. The developer has set out strict rules as to what they should be able to be done with the produced software and is well informed of the risks of ‘hacking’ and leaving security issues within the code. These steps have been taken to ensure the team does not breach these laws.

Just as the utmost care must be taken for the Computer Misuse Act. The same due attention must be taken for the Data Protection Act. This Law must be respected, and user data must not be delegated to any unauthorised personnel. The developer will also develop the project with the utmost security to ensure that users will not have their data unlawfully distributed.

### Further Analysis

Within the initial meeting between the developer and the subject specialist, the idea was put forward and discussed as to whether it was feasible or not. The subject specialist agreed the project was feasible and thought and added insight into what would require the most work and what would require the least. This was highly beneficial to the developer as this gave valuable insight into the time scales for the developers Gantt Chart.

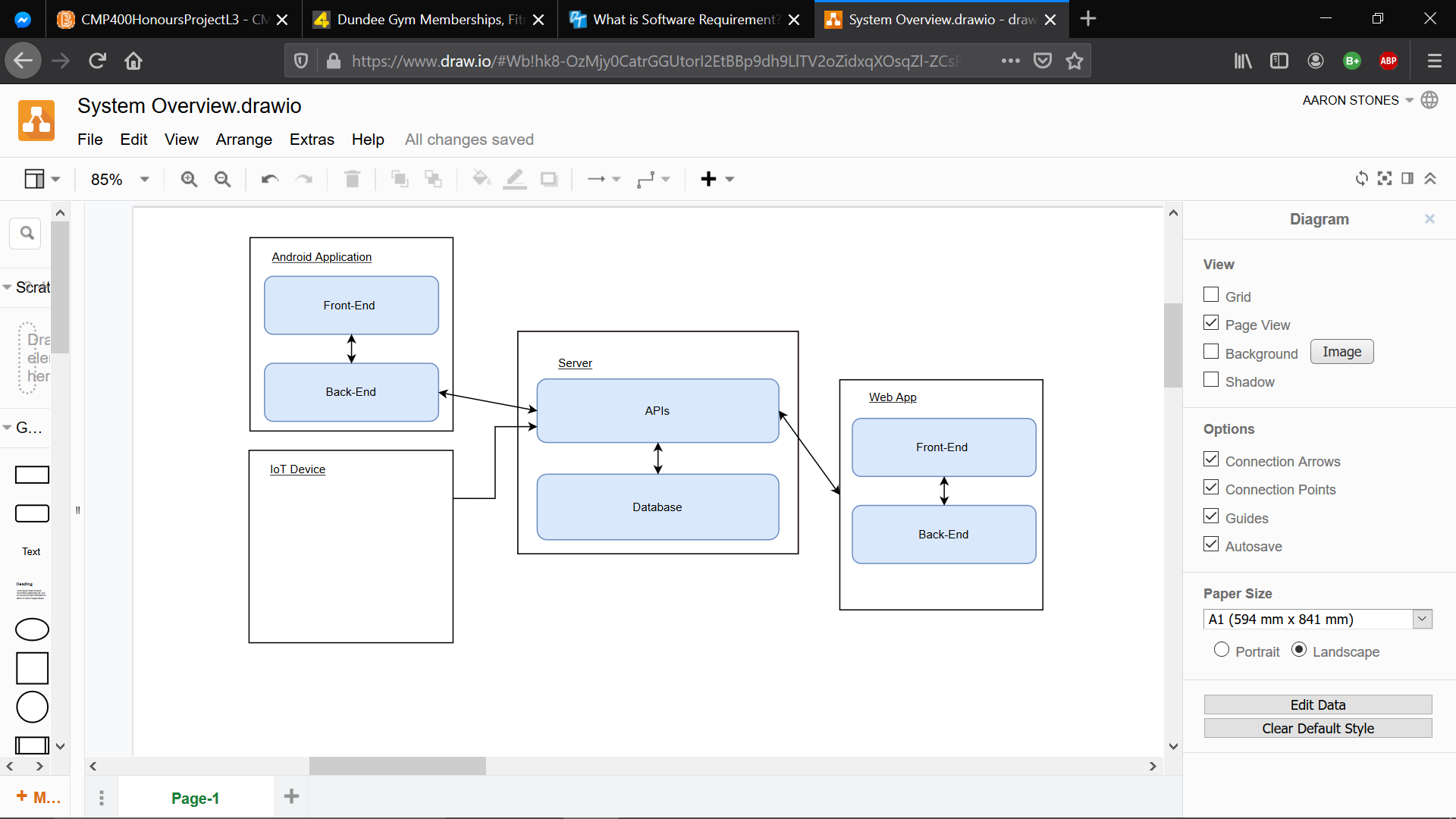
The Gantt Chart was a critical piece of documentation that was produced early on, this allowed the developer to show the subject specialist an accurate timescale as to when different stages of Design, Development, Testing and Evaluation would be completed. This also allowed the developer to have a timetable to adhere to, giving accurate representations of when the developer was ahead of schedule and behind it (in this case the developer would be needing assistance and would consult the subject specialist).

A review of the facilities at Abertay University had to be conducted to decide whether outside software needed to be utilised. This was not the case and Abertay University had all the necessary features required to develop the project. These were decided as A Website Application for the Medical Professionals to be able to monitor the patients. This will use technologies such as the LAMP (Linux Apache MySQL and PHP) stack, coupled with HTML (Hypertext Mark-up Language), JavaScript and CSS (Cascading Style Sheets). These were decided on as Abertay University has free to use servers which support these very well and the developer has a wealth of experience within these languages. Following this, Android Studio was selected to develop the Mobile Application; firstly as Android devices are some of the most commonly used devices in the world, also Abertay University uses the Windows 10 Operating System and to develop on iOS for Apple devices a Virtual Machine would need to be used to run MacOS and this would be awkward and cause issues during testing because the developer only has access to an Android running phone, so could not accurately prove this concept.

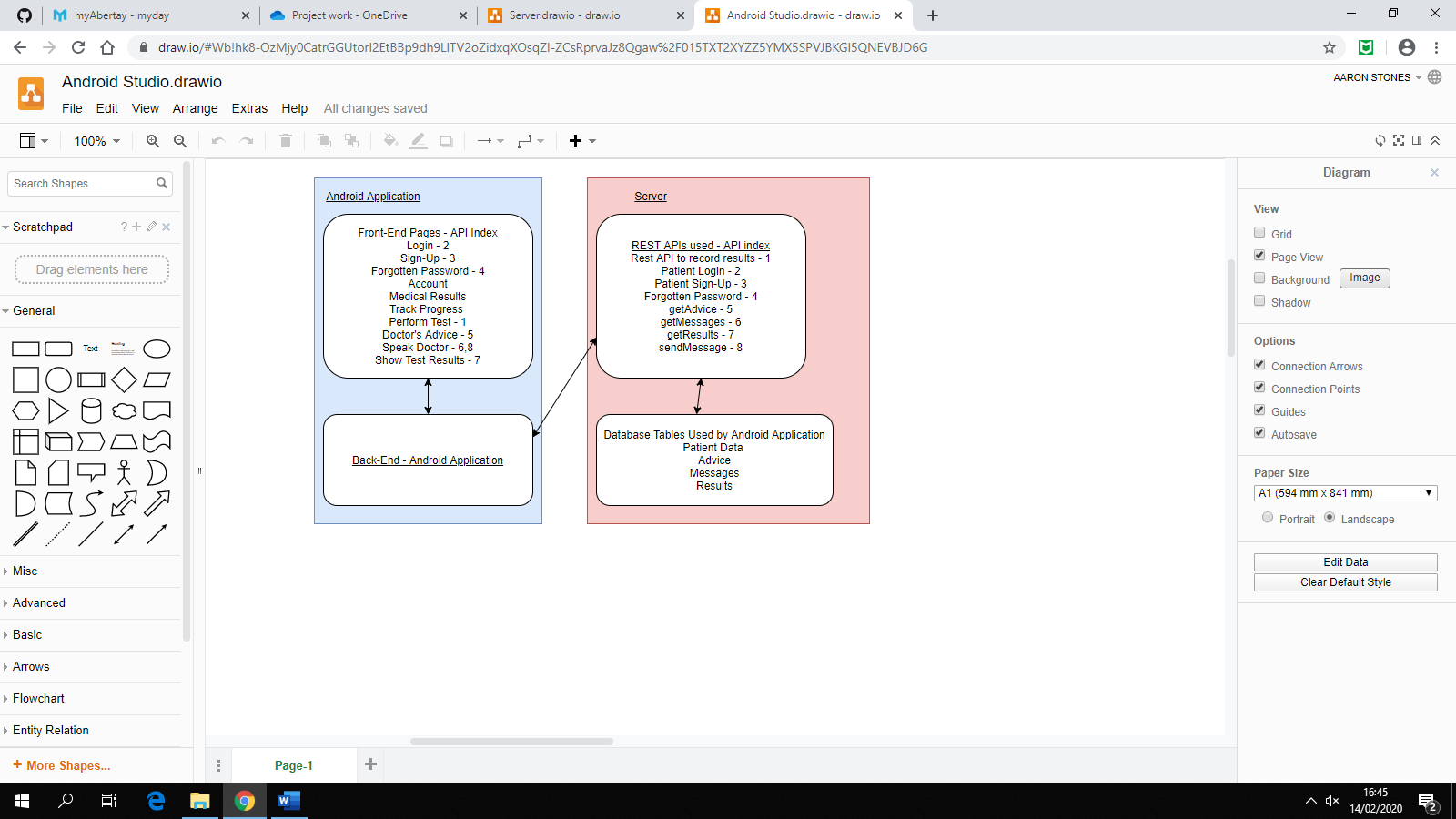
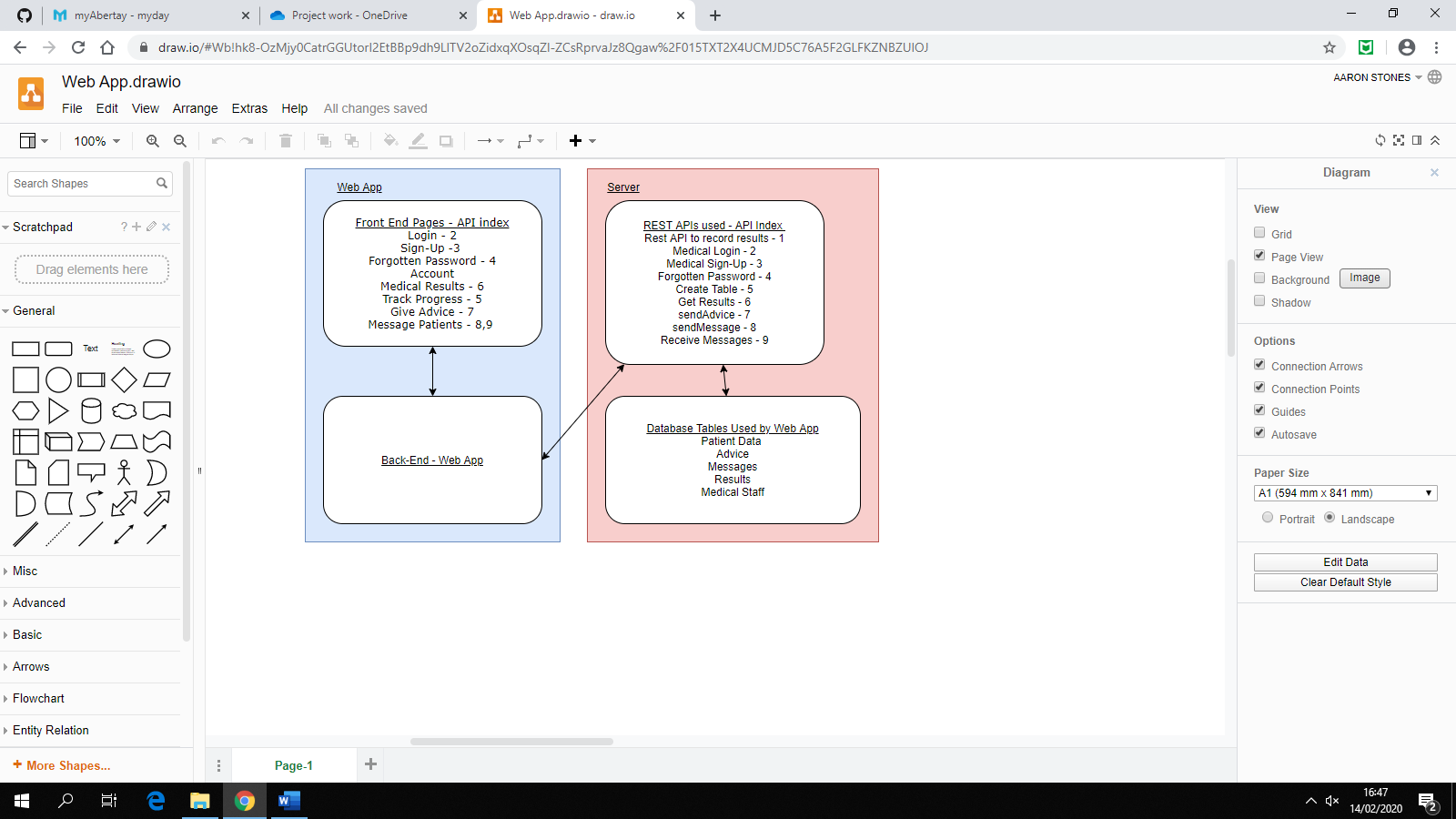
**Insert IoT stuff**

## 3.3 Design

As previously hinted towards, these devices must work in tandem to show the results from each on the medical professional’s website application. So, to initially understand the logic of the system, a System Diagram was created to show the communications to and from the server and between devices. As shown below.



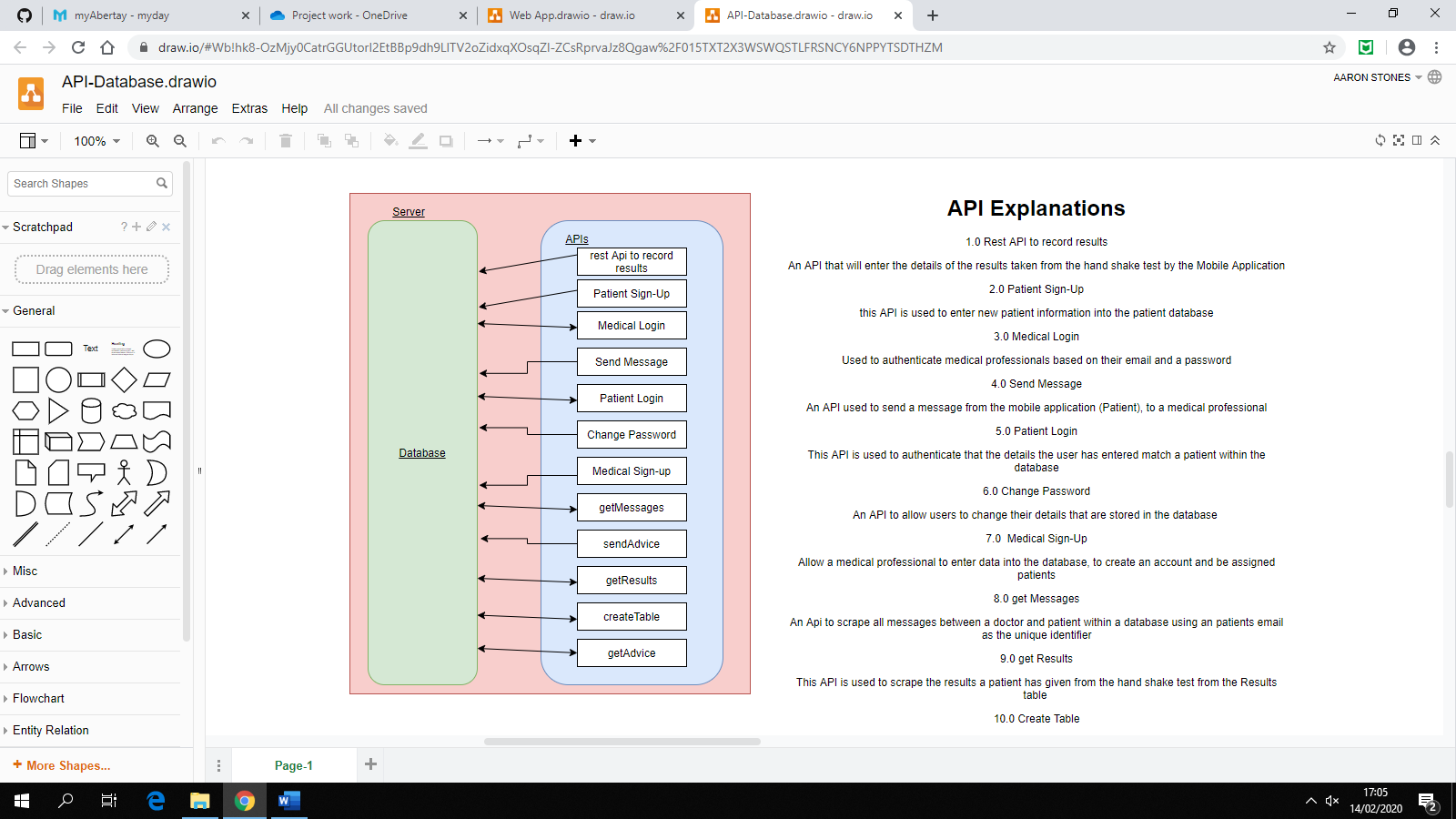
As shown above, all devices will send and receive data to and from a centralised server. This will allow all data to be kept within the same place and allows ease of access between devices and the data, using REST (Representational State Transfer) APIs (Application Programming Interfaces) within the server. Th server supports the backend programming language called php. Therefore, all REST APIs will be coded within PHP. The REST APIs will be contacted by multiple devices, for example, to record results as both the IoT device and Android device will be recording moist of the same results. This means that the same REST APIs can be used by multiple devices. A diagram has been created to show the communication between devices and the REST APIs.



These APIs used will have to store the data in some place, the developer has decided the best place to store the data is a MySQL database. This has been selected because the type of data being stored is unlikely to change as the measurements being taken are standardised (Blood Pressure, Heart Rate, Blood Oxygen and Temperature). MySQL databases are perfect for data types that are unlikely to be changed and for amounts of types of data that are unlikely to change. So, for standardised measures of health that have been used for decades this type of database is perfect to use. Also, Abertay University provides a free to use database of this type. Relationships are the basis of MySQL databases and within this project there is no change within that. Relationships have been created to decrease the amount of repeated data within the Schema. A diagrammatical view of this has been created and can be seen below.

**Insert database diagram**

The REST APIs will be used to communicate with this database, to store things like medial professionals’ information, results, patient information etc. A further diagram has been created to show the relationship between these REST APIs and the Database within the server. As shown below.



**1.0 Rest API to record results -** An API that will enter the details of the results taken from the handshake test by the Mobile Application.

**2.0 Patient Sign-Up -** this API is used to enter new patient information into the patient database.

**3.0 Medical Login -** Used to authenticate medical professionals based on their email and a password.

**4.0 Send Message -** An API used to send a message from the mobile application (Patient), to a medical professional.

**5.0 Patient Login -** This API is used to authenticate that the details the user has entered match a patient within the database.

**6.0 Change Password -** An API to allow users to change their details that are stored in the database.

**7.0 Medical Sign-Up -** Allow a medical professional to enter data into the database, to create an account and be assigned patients.

**8.0 get Messages -** An API to scrape all messages between a doctor and patient within a database using a patient email as the unique identifier.

**9.0 get Results -** This API is used to scrape the results a patient has given from the handshake test from the Results table.

**10.0 Create Table -** This creates the php table to show a medical professional the progress of a patient, based on their results stored within the results table.

**11.0 get Advice -** Gets the advice from the advice table to show a User so that they don't forget it. Entered by the Doctor.

## 3.4 Implementation

# Chapter 4 – Results

500-800 words

A factual presentation of your results which relate to the project aim

A description of the completed software/hardware and analysis along with test/evaluations/analysis results

Suitably present in:

* Tables/Charts
* Statistics
* Illustrations
* If too many use appendices

Put raw data in appendices

Don’t dwell on discussion of issues. Save to discussion chapter

# Chapter 5 – Discussion

2250-2500 words

Evaluate your findings/results

Comment on their significance in relation to the previous work on the same topic

Refer to your literature review where appropriate

Use the aims and objectives outlined in your proposal/introduction if appropriate to aid your evaluation, referring to initial project requirements

# Chapter 6 – Conclusions & Future Work

750-1000 words

What conclusions can you draw from your investigation?

What are the implications of what you have discovered?

How might further work in this area be continued?

# List of References

List all works used and refer using Harvard style – CITE THEM RITE

Write references in text and add to references section while you are writing

# Bibliography

List works that you have considered but do not refer to in text. Use Harvard

# Appendices

Used to stop text being cluttered and broken up:

* Tables of extensive data
* Code
* Legal decisions or laws
* Lengthy quotations
* Copies of sample questionnaires
* Start each appendix on a separate page and label A,B,C etc