

Using IoT in a data centre environment to reduce operation costs.

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Declaration of Originality

I, Ceri Puddle, declare that I am the sole author of this Project; that all references cited have been consulted; that I have conducted all work of which this is a record, and that the finished work lies within the prescribed word limits.

This work has not previously been accepted as part of any other degree submission.

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Date: .27/04/20

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Abstract

The abstract of this project is to carry out research on a typical data centre its associated topics. From this, the researcher will identify ways of improving energy consumption by designing developing and implementing an IoT system to carry out the following observations that can be made.

- Comments that can be made,
 - when are the peak load times and could cooling be reduced at these times to save energy?
 - Are there any hotspots in the room that are causing an unnecessary build-up of heat?
 - Is the humidity of the place staying consistent, therefore reducing the chance of static shock?
 - Does any of the equipment require maintenance due to a blocked filter or other overheating issues

In the report, you can find research into data centre cooling techniques, The use of IoT, Arrhenius equation, Wireless sensor networks and Computational fluid dynamics. References associated research can be found in the referencing section of this paper, along with a bibliography of books that provided a better understanding of the topics in question. Examples of code for the creation of the IoT system, including the database using MySQL and PHP. Finally, there is a conclusion that answers the hypothesis and theory. This paper was produced for the UWTSD for the degree of BSc Computer networking and cybersecurity.

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Chapter 1

1.1 Introduction

Computing is changing, with the implementation of cloud computing and the introduction of Bring Your Own Device. More and more reliance is placed on the networking services provided by companies such as Google, Microsoft and Amazon, who provide hosting services and large datacentres across the world.

There are many benefits to using cloud computing as a business; one of the most significant benefits can handle all the processing for your information can be done off-site. This means that a person can use low power devices that are portable to complete complicated tasks that would otherwise require expensive and powerful computers/devices.

A datacentre is the heart of cloud computing, in a large datacentre such as one created by amazon. There are thousands of different computing elements such as switches, routers, and dedicated servers, just to name a few. Having all this computing power, all in one centralised place produces a lot of wasted energy in the form of heat. The research shown in this review will highlight why this is such a problem and ways to go about preventing any issues that can be caused by heat

The research criteria will be choirs from multiple different sources such as academic papers, industry papers and articles. The age of the data must be at least from 2006 onwards as this was when the concept of cloud computing was introduced.

1.2 Aim

- To create a temperature and humidity monitoring solution using IoT. That would reduce the energy consumption by better directing the cooling and distributing the heat load of the data centre components.

1.3 Objectives

- Research data centre operations and the main costs of a datacentre
- Research solutions to cooling within a data centre
- Research related work into data centre temperature monitoring
- Research wireless sensor networks functions and implementations
- Design, Develop and implement a temperature and humidity monitoring solution
- Implement time management into the project

1.5 Related work

A paper published by IEEE named “Data centre temperature monitoring with ESP8266 based Wireless Sensor Network and cloud-based dashboard with the real-time alert system”, is related closely to this research topic. In this related work, there was a focus on making a real-time system that would alert the datacentre management team if the temperature hit a certain threshold. This allows the management team to respond quickly to any potential issues. The solution would come with a cloud based dashboard that could be monitored remotely.

The approach of this paper is to collect temperature and humidity data from them within the data centre and its components over a period. The data can then be studied and analysed to find any potential hot spots in the data centre design. From this data, the management team can distribute the most used devices in the data centre and reduce the energy required to cool the components.

1.6 Hypothesis

Can the use of IoT help reduce the cost of operating a data centre?

By implementing a system such as one that can be created using IOT, It could reduce the energy consumption of the data centre and save costs in not only utility bills but also prolong the life of devices by identifying any concentrations of heat and humidity.

Chapter 2 -Research and review of literature

2.1 Introduction

This chapter aims to show in detail the main theories and topics related to the area of study. Within this section, there will be the identification of positive and negative factors that can influence a data centre and show industry research published across multiple different media such as Journals, Articles, Documents, and web sources.

The focus of the study as highlighted by the research methodology is to positivistic research; This is because the data that is required for this type of project needs to be quantitative and is going to take a deductive approach, more about this papers research method can be found in chapter 3.

2.2 What is the data centre?

A datacentre is a large facility that houses a whole network of computers and storage devices that other entities such as business and other organisations can use. [1] The number of devices that can be in datacentre can vary on the organisation, for services provided by Google and Amazon, for example, the number of devices is in the hundreds if not thousands.[2] These servers and devices are smaller than they used to be and are running 24/7 without any downtime.[1][3]

The data centre can provide many different functions such as organise, store and process large amounts of data. These devices can enable the delivery of shared services such as email and file sharing. [1]

2.2.1What devices are in a datacentre?

A data centre comprises of many different elements. These elements of the data centre work in conjunction with one another to provide a network that can offer services to businesses and other organisations. Within you can also be expected to find racks that are used to house the components and organise the connected IT equipment [1]. A datacentre must also contain enough infrastructure, such as the power to support itself. This is done through the integration of uninterruptible power supplies and backup generators that reduces the risk of downtime due to a power failure and prevents the loss of data and service.

Types of equipment in a data centre:

- Networking equipment such as routers, switches, and firewalls
- Computing elements such as dedicated servers
- Security systems
- Network Operations centre
- Fire protection systems
- Temperature control
- Cabling systems

2.2.1 Energy Consumption, efficiency, and cooling?

There is a growing need for the use of datacentres and datacentres are responsible for consuming 1%-3% of the world's total energy. There is currently an ever-growing appetite for networking services that are growing 30% each year. Power consumption is one of the highest recurring cost of a data centre, and the cooling infrastructure is a big part of datacentre operation and one of the most important. A study was carried out to identify the primary sources of data centre energy consumption. This figure falls in line with other articles such as one that is published in the book Cloud computing for dummies stating that traditional data centres are typically spending 25%-35% [figure1] of upkeep just on cooling the equipment.[25]

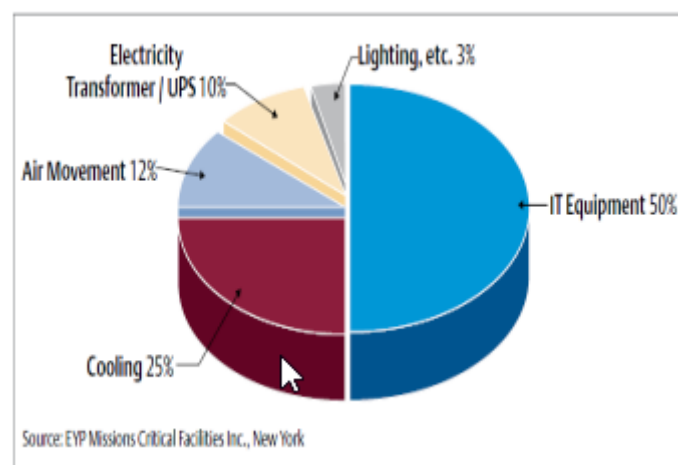


Figure 1, The following figure shows a chart of the costs related to a datacentre [4]

Most data centres use air conditioning units to reduce the temperature of ambient air

This shows the total power consumption of a typical datacentre, it shows that cooling a datacentre is the second-highest energy-consuming element. The push for the need for reducing energy consumption for both environment and cost reasons has resulted in equipment being made with cost-saving measures and efficiency in mind. According to this news article [4] with energy prices increasing energy efficiency is becoming more and more essential to keep the datacentre viable for use.

There are multiple different implementations of cooling techniques that are in place; one of the most used methods is to place the server racks onto a raised floor system. This system implements CRAC unit (Computer room air conditioner) to push fresh air through the floor. [22]

The goal of this research is to highlight the different elements of a data centre and what the main costs are to operate a typical data centre, In other research, there is mention of cloud computing data centres that have slightly different running costs due to the scale and location of these sites.[25]

2.2.3 Raised Floor cooling system

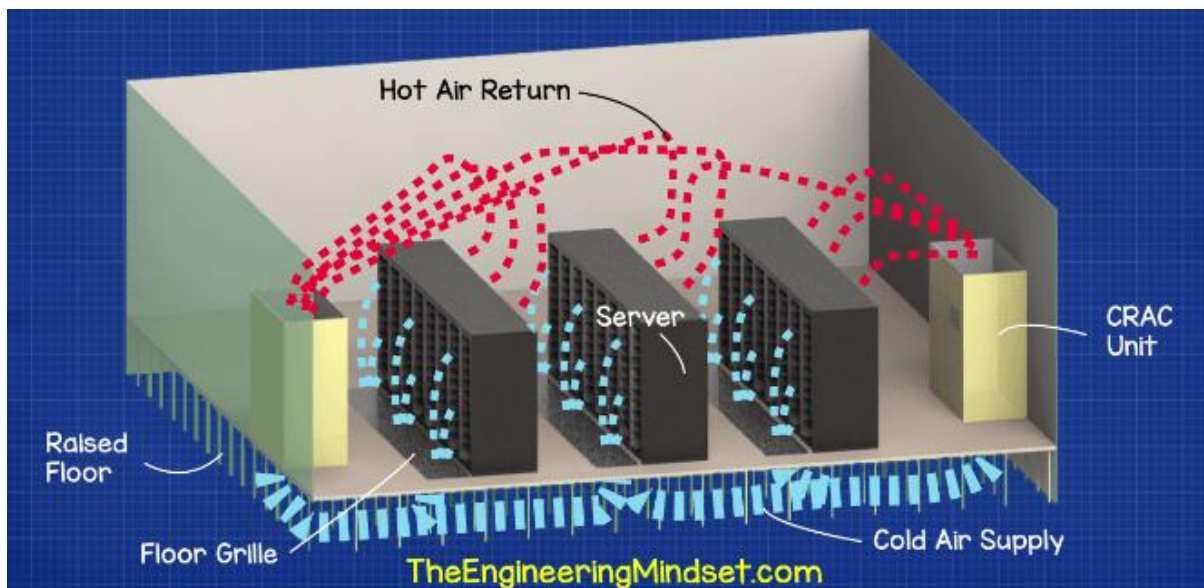


Figure 2 shows an example of a raised floor cooling system [22]

As shown in the figure above there is an airflow system in place, using natural convection that heat rises this system pushes cold air-conditioned air from the bottom of the room with a raised floor and returns the hot air. In older methods of the server room, designed servers were placed different orientations without the consideration for heat management.

“In the early days the server racks were positioned facing different ways, and engineers soon realised this was very inefficient because the fresh cold air was just mixing with the warm discharge air of the servers and this meant that the servers were receiving different air temperatures, some hot some cold and this lead to higher energy consumption and a high failure rate of servers.”[22]

This proved to be inefficient and reduced the lifespan of the server room components. To combat this, the data centre components were oriented the same way, this did improve the efficiency slightly, but there is a good chance that discharged air could just get mixed with the intake air. This caused ambient air temperature to rise. [22]

The main take away from this airflow system is that it would be very inefficient in a large data centre with more than a couple of racks. While this is one of the most common and least costly implementations of data centre cooling.

2.2.4 Hot and cold aisles

Another strategy that has been used and is common is the Implementation of hot and cold aisles [figure3]. Through this method, there is a no physical separation between hot discharged air and the fresh crisp air. Like the raised floor system cold air rises from the floor filters and is pulled into the devices through cold aisles and discharged through the device to a hot aisle, which is then drawn back in through the CRAC units. [22]

This requires the setup and design to be perfect for getting the proper results that it was initially designed for. Small imperfections such as gaps in the flooring could result in an air leak which in turn could lead to cold air mixing into the hot aisle.[22]

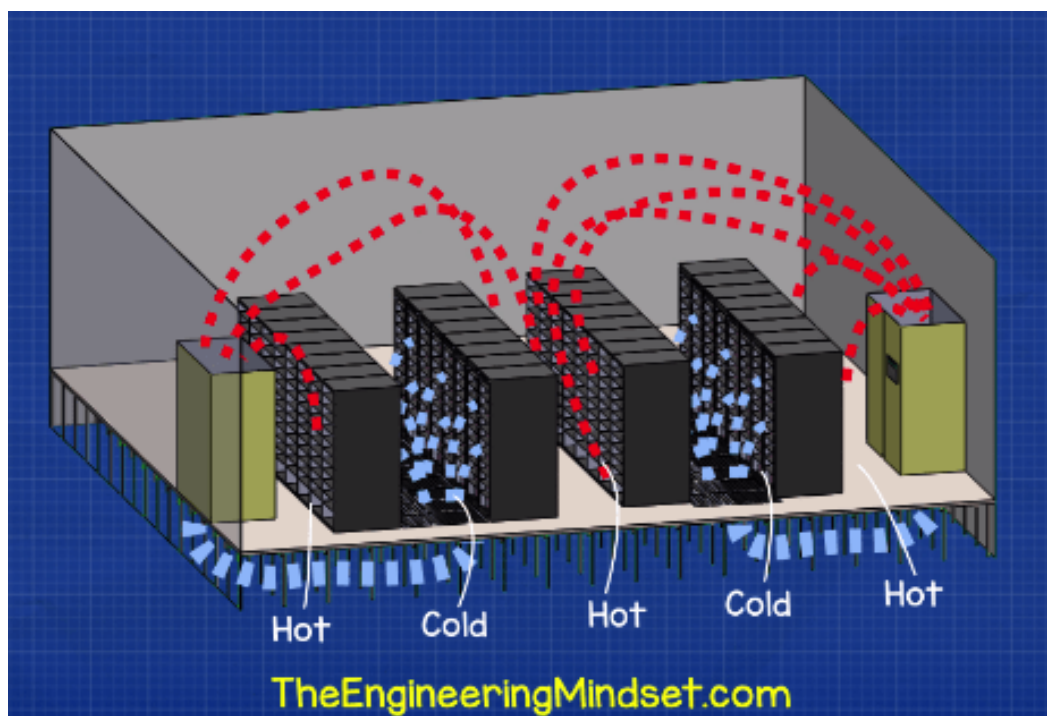


Figure 3 shows an example of a hot-cold aisle design [22]

Hot and cold aisle containment

This strategy is using a physical separation between the hot and cold air [figure4]. This allows better, more directed airflow and eliminates the mixing of hot and cold air. Cold aisle containment is the more popular option because it is easier to implement and retrofit to existing designs. Cold aisle containment is based on the cold air being pushed into the aisles, and then the hot air being discharged to the rest of the room. Hot aisle containment works based on a dropped ceiling design, so the cold air is forced into the entire room, and then the hot discharged air is pushed through the aisles into the ceiling where it is then drawn back into the CRAC unit. Hot aisle containment is the most popular method of cooling when be used with free natural cooling.[22]

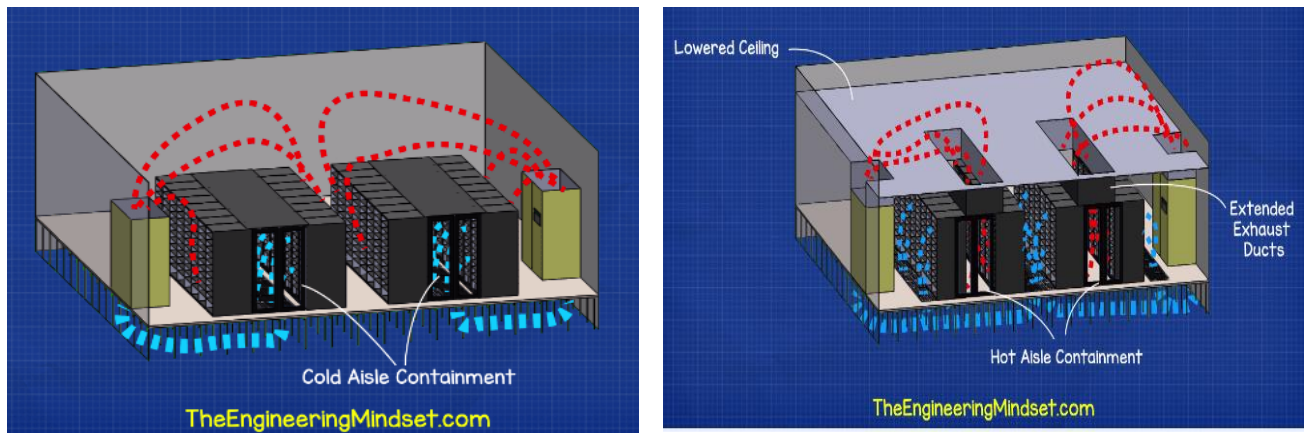


Figure 4 These two examples show different containment methods, the one on the left is cold aisle containment and the one on the right is hot aisle containment [22]

Data centre free cooling

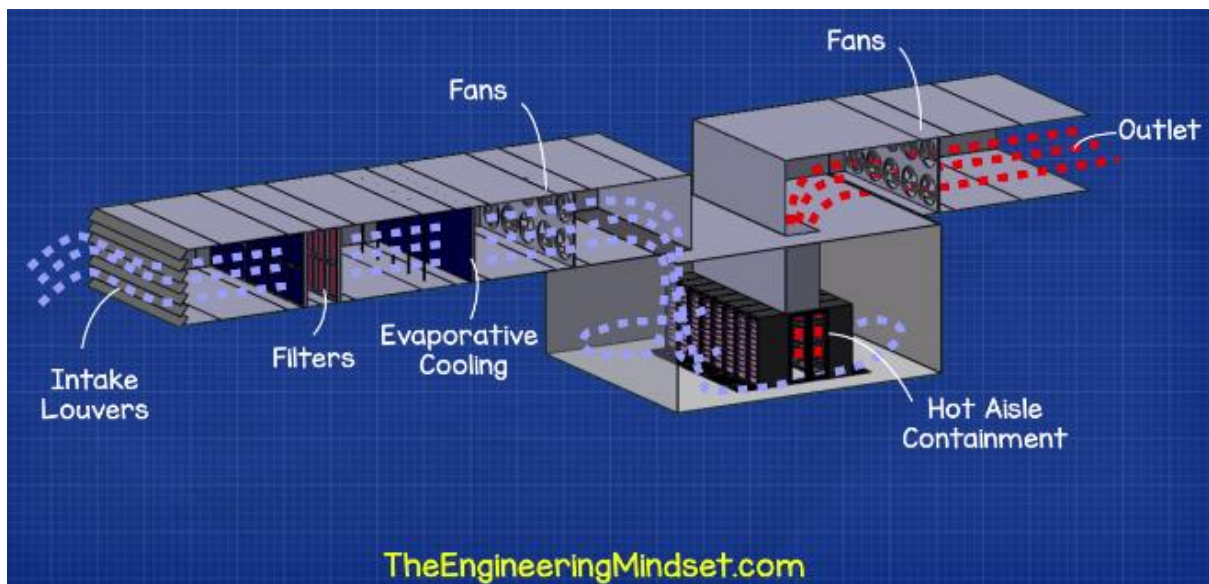


Figure 5 shows an example of free data centre cooling ducts

With the ever-increasing prices of energy companies like Microsoft and Amazon, IT has been looking at natural ways of reducing the temperatures. For example, Amazon IT has built a data centre on the shores of Iceland in order to reduce the cooling cost of the data centre. [11] Google has followed the same idea as Amazon IT and has opened a new data centre in Finland around the Arctic circle.

Microsoft has also been planning to implement mini datacentres under the sea. This is a quote from Sean James, a Microsoft engineer. This type of design can only be achieved in certain parts of the world that has the right ambient temperature to leverage the benefits of free natural cooling. Fresh air is drawn through intakes which are then filtered and humidified, after that the air is forced into a hot aisle containment design. Fresh air can contain harmful particles that can damage and lead to the premature failure of data centre components. This includes salt, dust and moisture.[22]

“reduce construction costs, make it easier to power these facilities with renewable energy, and even improve their performance,”[11]



Figure 6 is an image taken of one of Microsoft underwater data centre capsules [11]

Microsoft is leading the way in new data centre cooling techniques, [11] Companies are looking at ways to Improve the cooling strategies within the data centre. Microsoft has decided to take the idea of the underwater data centre. This is the following quote from Sean James, a Microsoft engineer.

they think it could also “reduce construction costs, make it easier to power these facilities with renewable energy, and even improve their performance,”

[11]

This does come with some new sets of challenges, such as the following.

- The data centre components must stay dry
- The container needs to be salt resistant and inhibit corrosion that might otherwise be a detrimental effect in an above-ground data centre.
- The container must be free of any wildlife such as barnacles and another manner of sea life that might inhabit the unit.

The main reason that Microsoft has decided to take on such an endeavour is for free cooling. In the initial testing, they found that water below the surface only varies between 14-18C. Therefore by taking advantage of the cold water around the data centre around the pod. On their land data centres, Microsoft uses the cooling method of evaporation to cool the surrounding air there for consuming more water.

2.2.5 Computational fluid dynamics

The use of CFD (computational fluid dynamics) can be used to compare the different designs of different server room setups. Simulation programs such as Simscale is used to design and study the airflow and temperature of a given model. This allows designers to get powerful insights into the proposed designs and helps optimise the design.

The following image is an active simulation of a data centre hot and cold aisle. Through analysis of a CFD, designers can identify any hot spots or flaws in the design. The following configuration uses hot and cold aisles with compartmentation. [23]

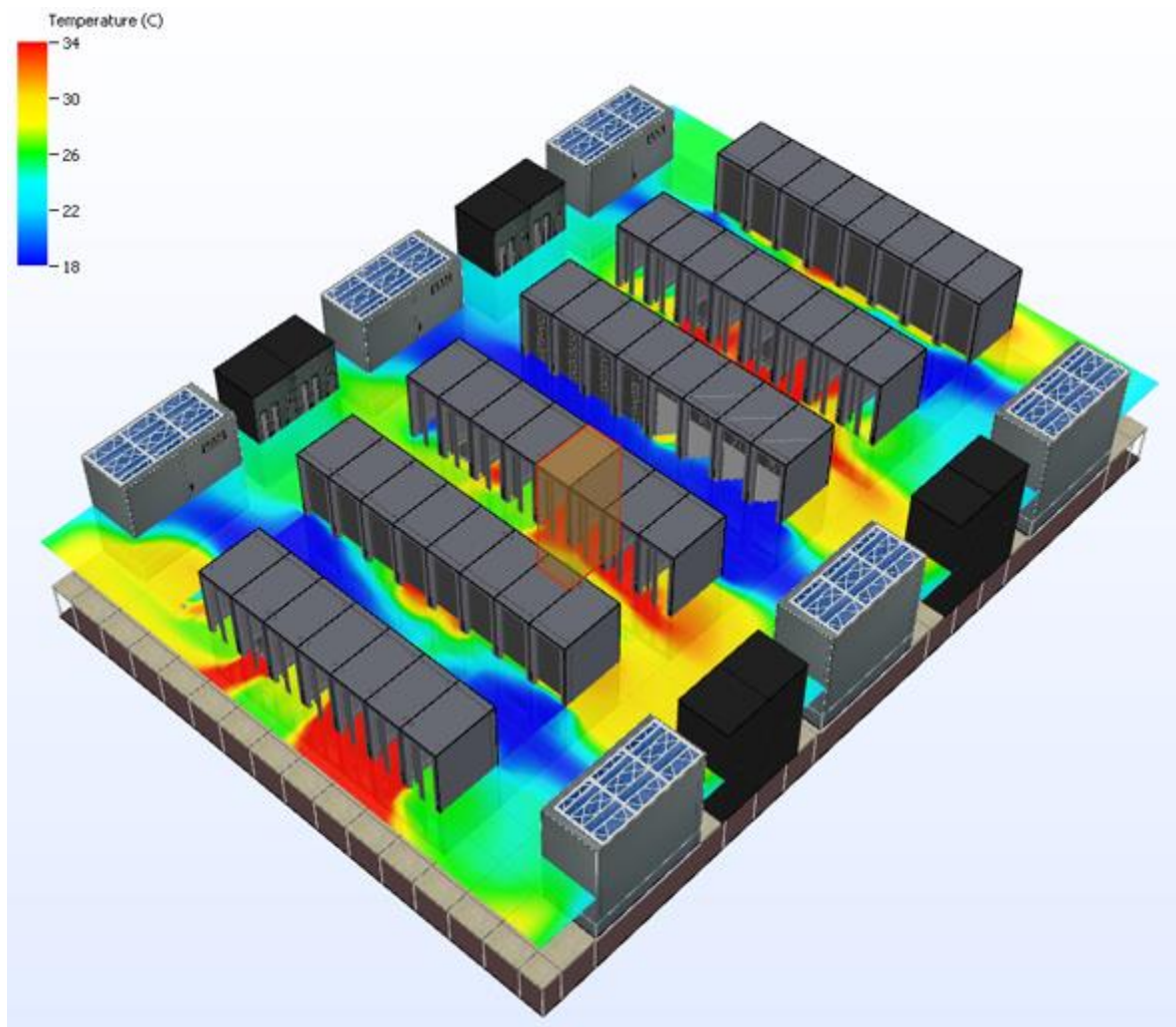


Figure 7 shows an example of CFD in use

The use of CFD can optimise the power and thermal characteristics of a data centre design. Using the proposed model and thermal limits, the designers can decide on the best cooling method based on the following requirements of total thermal load and the size of the space of the server room. The conclusion that can be drawn from this research is that data centre design is evolving, and more emphasis is being placed on the requirement of lower running costs and the reduction of the environmental impact. CFD is one of the newest technologies in data centre design and its proving to be one of the most reliable tools available to a data centre architect.

2.3 Arrhenius equation HTOL model

SVANTE A. Arrhenius proposed a model for ionic chemical reaction rates in 1884, and this is one of many equations that is used to predict the failure rates probability due to chemical effects. This shows the exponential impact that temperature has on semiconductor devices [21].

The Arrhenius equation has been taken and further developed in many different applications; for this research paper, there will be a focus on the HTOL model, which will be explained further on in the chapter.

A PDF that was produced by Microsemi in 2012 investigates calculating reliability based upon the HTOL model (Arrhenius High-Temperature Operating Life). The scope of the study is to calculate and predict the life expectancy of semiconductors when exposed to prolonged heat.

This work was created to show how the HTOL model functions and how to use the equation in calculating the reliability and define the terms and definitions of what each part of the equation means. This allows the user of the HTOL model to get a better understanding of how it functions and how it can be used to display the effects of acceleration factors such as rising heat. In the PDF, there is mention of the Acceleration factor that is used in the calculation of the HTOL model.

“Acceleration Factor (Af) is the test time multiplier derived from the Arrhenius equation. This equation calculates the time acceleration value that results from operating a device at an elevated temperature.” [8]

This variable is the primary variable that would influence the semiconductor lifespan; this can be backed up by the previous sources. At the figure below, they have shown an implementation of the HTOL model using Excel and the calculations that are used as well.

Microsemi Reliability Calculator
MicroNote-1004
By Paul Eberhart, Director of Reliability, paul.eberhart@microsemi.com

Reliability Calculator using Arrhenius HTOL Model
INPUT DATA: Do not use screening data for reliability calculations.

Number of Failures (f)	Number of Devices Tested (D)	Test Hours per Device (H)	Test Temperature (°C)	Use Temperature (°C)	Established Activation Energy (eV)	Chi-Square (X²) @ 50% Confidence Level (S)	Acceleration Factor (Af)	Total Number of Failures (F)	Total Number of Device Hours (DH)	Equivalent Device Hours (EDH)
0	220	1000	125	55	0.7	4.045	77.94	1	220,000	30,474,523
1	450	350								

Failure Rate (λ_{hour}) = 6.64E-08
FIT: Failures in Time (λ per billion hours) = 66
MTTF_{hour}: Mean Time to Failure (θ in hours) = 15,063,338
MTTF_{year}: Mean Time to Failure (θ in years) = 1,720

Parameters & Constants
f = number of failures or rejects
D = Number of Devices Tested
H = Test Hours per Device
T (Calculation Temperature in Kelvin) = Celsius + 273°
T_{use} = Test Temperature (HTOL or other burn-in temperature)
T_{use} = Use Temperature (standardized at 55°C or 328°K)
E_a = Activation Energy (eV)
X² (Chi-Square) is the probability estimation for number of failures at α and v
α (alpha) = Confidence Level for X² distribution; reliability calculations use α = 60% or .40
v (nu) = Degrees of Freedom for X² distribution; reliability calculations use v = 2n + 2
A_f = Acceleration Factor from the Arrhenius equation
k (Boltzmann's Constant) = 8.617 × 10⁻⁵ eV/°K
DH (Device Hours) = D × H
EDH (Equivalent Device Hours) = D × H × A_f
λ_{hour} = Failure Rate per hour
FIT (λ_{hour}) = Failures in Time = Failure Rate per billion hours
MTTF = Mean Time to Failure

Equations

$$A_f = e^{\frac{E_a}{k} \left(\frac{1}{T_{use}} - \frac{1}{T_{test}} \right)}$$

$$FIT = \lambda_{FIT} = \lambda_{hour} \times 10^9$$

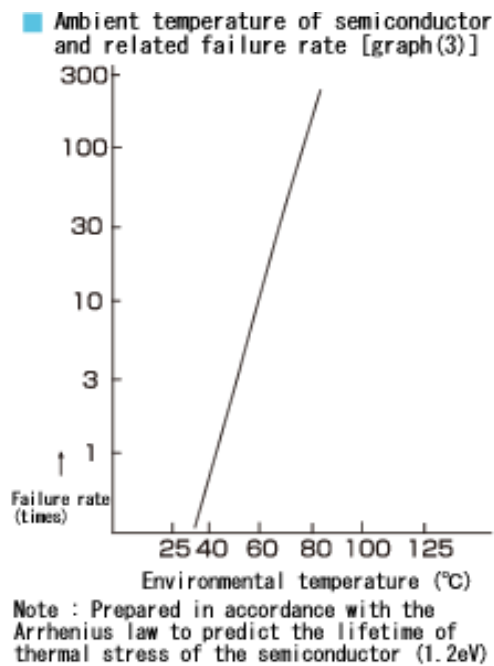
$$\lambda_{hour} = \frac{X^2(\alpha, v)}{2 \times D \times H \times A_f} = \frac{X^2(\alpha, v)}{2 \times EDH}$$

$$MTTF_{hour} = \frac{1}{\lambda_{hour}} \quad MTTF_{year} = \frac{1}{\lambda_{hour} \times 24 \times 365}$$

Figure 8 shows the use of the reliability calculator created by Microsemi [8]

From the results of this reliability calculator using the HTOL model, a semiconductor designer can use quantitative to show the reliability of a device over a period known as MTBF.

With these different devices can be compared and the effect of heat can be studied to find the minimum and maximum operating temperature.



The following graph [figure 9] shows the effect of ambient temperature and the related failure rates of semiconductors. This graph is assuming that the semiconductor is running continuously at 1.2v. The figure shows that there is a correlation between the environmental temperature and the amount of temperature-related failures. [22]

Figure 9 shows a graph that was created to show the effect of ambient temperature on semiconductors [24]

2.3.1 Meantime between failure rates

MTBF mean time between failure rates is a term used by manufacturers in a range of different industries. MTBF is a measurement of how reliable a component is over a period that is measured in hours. For example, a review on a Seagate HDD boasted 1 million hours MTBF. This is used in the HTOL model to predict the failure rates of semiconductors. [17]. MTBF is calculated using a couple of controlled variables. For this example, there was insight published by Seagate on how they calculate the MTBF. Although there is not a full step by step procedure, there is useful information on how this is carried out.

“Hard drive reliability is closely related to temperature. By operational design, the ambient temperature is 86°F. Temperatures above 122°F or below 41°F, decrease reliability. Directed airflow up to 150 linear feet/min. is recommended for high-speed drives.”

[18]

The following statement states that heat has a direct impact on the lifespan of hard disk drives in relation to the MTBF. Although this article is directly related to HDD, there is a shared consensus in IT that heat has an adverse effect on computing.

The main take away from this research on Arrhenius's equation is that it is a comprehensive theory that has been taken and shaped by many other individuals of the years. This example of the equation is based upon reliability for semiconductors. This provides insight into the importance of keeping within the operating temperatures of a product.

2.4 Bring your own device

A key topic that is relevant to this study is the bring your own device. Or as it is more commonly known in the IT industry as BYOD. BYOD is a concept that allows workers to bring their own devices, such as laptops, smartphones, tablets, for example, and complete and carries out their job from their own personal device.

Devices such as tablets and smartphones have seen a considerable rise in popularity over the past decade and have the features and capability to carry out many different tasks at once [14]. There is a vast variance in the implementation of BYOD due to the business requiring different needs. There are some key fundamentals that make up a BYOD set up, such as the need to provide the workers with a private connection (Virtual Private Network) in order to encrypt any plain text data and protect the data from any prying eyes and access to network resources such as shared drives and virtual machines for example. An employee would be working off the company's servers while using their own personal device as an interface to the data and virtual machines on the server. This method allows the user to have low power, lightweight and cost-effective equipment due to all of the processing power being handled by the company's servers, thus increasing the load expectancy on the servers.

There are alternative implementations of BYOD. These are known as COPE and CYOD. COPE (Corporate owned, personally enabled) and (choose your own device) Are implementations that search for the best cost, management, and productivity [20]. When an employee is enrolled in one of these programs, the individual will be allowed to choose from a pre-approved range of devices. In these implementations, the company is responsible for sourcing these devices and pay for them.

By providing workers with network resources such as virtual machines, for example, the worker can work across multiple different devices at any given time [15]. There are numerous advantages to implementing a system such as this, here are the following advantages and disadvantages.[15]

2.4.1 Advantages of BYOD

- Reduced cost to the business
 - Dependent on the industry, there is a possibility that the company could see a reduction in price if workers are available to bring their own device. This relies on the fact that the business will not need to supply devices to each employee.
- Increased Employee satisfaction
 - Employees could benefit from the comfort of using a device that they are more familiar with and in turn, will provide the employer with better productivity. For example, if a worker is more comfortable using an apple mac keyboard compared to a standard keyboard from maker like Dell or HP, for example.
- Flexibility
 - Another advantage of BYOD is flexibility. Flexibility allows a worker to work from pretty much anywhere they can get connected to the internet. This

opens opportunities for mobile works or the potential to work from home. This will more likely attract more top-quality employees.

2.4.2 Disadvantages of BYOD

- Security
 - Security is one of the significant issues of BYOD. Employees would be accessing personal and sensitive information on their personal devices. This can prove a significant challenge for a business. When a company owns a device, they can control how it is used by implementing security policies. Another problem is making sure that all the devices have full protection from malware and other computer viruses.
- Supporting multiple different devices
 - There is a wide range of devices available for consumers to buy compared to businesses. When a company buys a new device, they are shortlisted to a small number of devices to support. With the implementation of BYOD, IT staff must provide additional support across multiple different devices and operating systems. This means that it can take longer to issue security patches across numerous different software systems.
- Scalability
 - Scalability can be a disadvantage to smaller business as they do not have the network resources required to implement such a system. Although cloud solutions are available, it might be variable until there is a necessity for the implementation for such a system

2.4.3 Working from home in relation to Covid-19

At the time of writing this paper in April 2020, the United Kingdom government has issued a complete lockdown of the country, limiting the movement of its citizens and calling all non-key workers to work from home. This is because of the ongoing pandemic of Covid-19, which has become a global pandemic over the past two months. Due to the importance of BYOD now of writing, it was included in the research as it will create a considerable amount of stress on data centres and networking services.

This has pushed business to look towards cloud-based solutions to provide their employees with the equipment required to work from home. With more reliance placed on networking services due to the high demand for internet traffic, companies and businesses need to keep their cloud-based / networking services working and operational. Due to the need for non-essential work to be carried out at home, many companies are implementing either a BYOD policy or something similar.

“Employers and employees should discuss their working arrangements, and employers should take every possible step to facilitate their employees working from home, including providing suitable IT and equipment to enable remote working.”

[19]

2.5 What is IoT?

Internet of things is a concept that everything is connected to the internet, there are multiple different implementations of IoT in everyday devices, for example, IoT is being implemented into security systems such as smart doorbells and door locks. IoT is being developed and is proving to be a very current and relevant solution to everyday problems such as traffic and pollution management, for example. It has been predicted by experts that more than 50% of new businesses will use IoT by 2020. [17].

The figure shown below is a graph that shows the total spending on IoT between the dates of 2017 to 2019. In the chart that was released in 2019 it shows some of the industries that are leveraging the use of IoT.

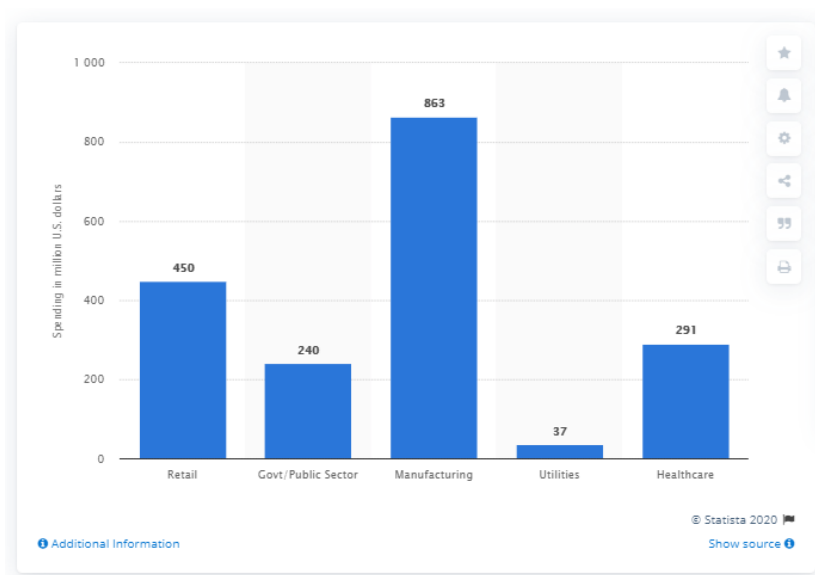


Figure 10 shows the use of IoT in industries [17]

IoT will be implemented in the hardware solution of this project and it's good to understand that there are multiple different implementations of IoT as it has the ability to be made to carry out specific tasks as well as numerous other functions. Systems have been developed to carry out particular tasks, and for example, in Switzerland, there are farms who have implemented IoT on to feeding machinery to monitor and improve the quality of life for their livestock. Therefore improving the dairy industry in Switzerland.

The use of IoT within the project will allow the researcher to create a group of sensors that would monitor and report the temperature and humidity of the devices within the data centre.

2.5.1 WSN

What is a WSN (Wireless sensor network)? A wireless sensor network is a network that has sensors, controllers, and a communication system.

Within the project, there will be a focus on the creation and implementation of a WSN. There are two elements that are required for the WSN. The design of the sensor node and the network architecture.

The sensor node consists of 4 base components: Power supply, Sensors, Processing Unit, and the communication unit. The combination of these four elements makes up a proper sensor node device. [12]. The job of the sensor to gather information based upon a physical process or physical occurrence. It is then translated into electronic signals that can be measured in a quantitative manner.

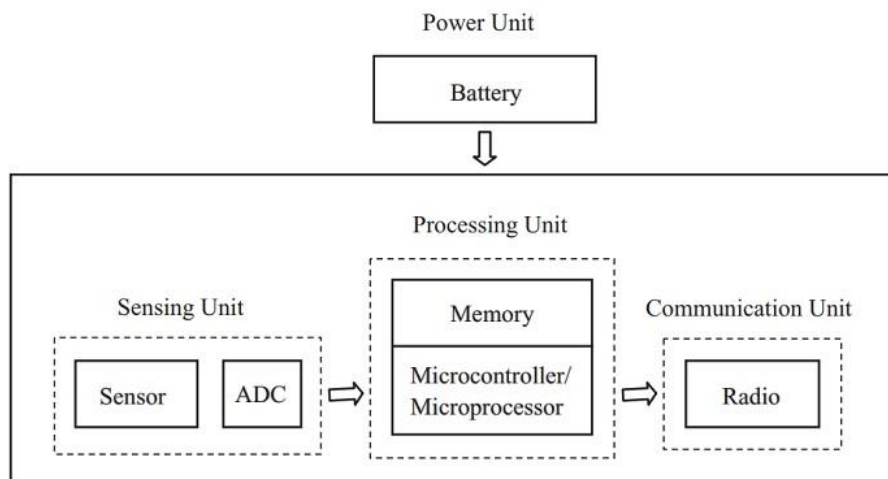


Figure 11 shows the design on a sensor node [12]

2.5.2 Classification of a WSN

WSNs are application-specific based and are creative and implemented based upon the requirements of the application. [24] This means that WSNs can vary in their design. Irrespective of the use case. WSNs can be classified as one of the following.[12]

- Static and Mobile WSN
 - In most use cases sensor nodes are static and are fixed without movement. Some applications may require int implementation of mobile sensor nodes such as animal tracking.
- Deterministic and Nondeterministic WSN
 - A deterministic WSN the position is of the sensor is fixed and calculated. This can be difficult in harsh environments and rough operating conditions. Due to these issues, there needs to be a complex system to control the sensors.
- Single Base Station and Multi Base Station WSN
 - A single base station implementation uses one base station to connect to the user. This means that the base station needs to be close to all the sensors in the sensor region. A multi-base station allows a network to be spread over different areas by using multiple base stations for the sensor to communicate.
- Static Base Station and Mobile Base Station WSN
 - The static base station is a fixed station that does not move. This is placed in the sensor region. Mobile base stations move around with the other sensors, this reduces the load on the sensors and saved power

- Single-hop and Multi-hop WSN
 - A single hop WSN is when a sensor is directly connected to a base station. In a multi-hop, Cluster nodes relay the data to the base station.
- Self – Reconfigurable and Non – Self – Configurable WSN
 - A non-self-configurable WSN requires a controller to organise the sensors into a network; the job of the controller is to then collect the data. A typical configuration of the sensors would be self-organising.
- Homogeneous and Heterogeneous WSN
 - In a homogeneous application, the sensor nodes all have a similar energy consumption. In heterogeneous WSN, sensor nodes have varying loads and power consumptions.

“Wireless Sensor Networks (WSNs) are vulnerable to faults because of their deployment in unpredictable and hazardous environments. This makes WSN prone to failures such as software, hardware, and communication failures.”[24]

It is essential to design the WSN for its particular purpose as a misjudged implementation could result in failures and a useless system.

Environmental factors

- Electromagnetic interference
- Dense and reflective materials
- Power surges
- Out of bounds issues

There are some standard designs that a WSN can implement. This is based on the number of devices and the use case of the WSN. The network architecture consists of the sensor region, Base station the internet and the user. [24]

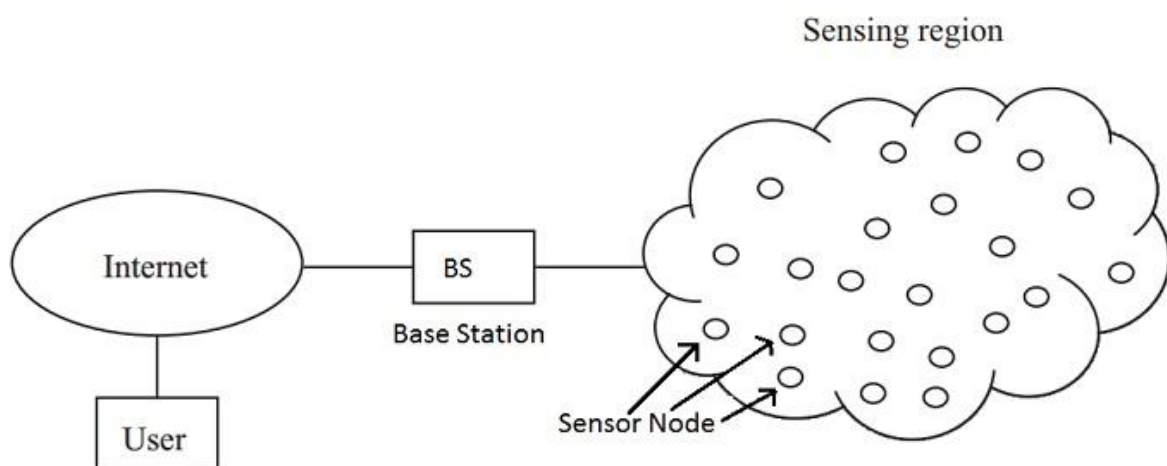


Figure 12 shows the depiction of a typical WSN [14]

2.5.3 Single hop and Multihop

The sensor nodes are deployed in an area to co-operatively monitor the physical environments. There are two basic ways that a sensor node would interact with a base station of network architecture. [24]

- Single hop method
 - A single hop is the method of data transmission from the sensor to the base station; in this method, the sensor is directly connected to the base station. This is the most straightforward implementation, but it does mean that the total amount of supported sensors is reduced. The sensors will also only be able to cover a small geographical area.
- Multi-hop method
 - This is the more complicated method; in this method, the data takes multiple hops over other sensors to connect to the base station. This allows the sensor nodes to be further away geographically and it is possible to use more sensor nodes

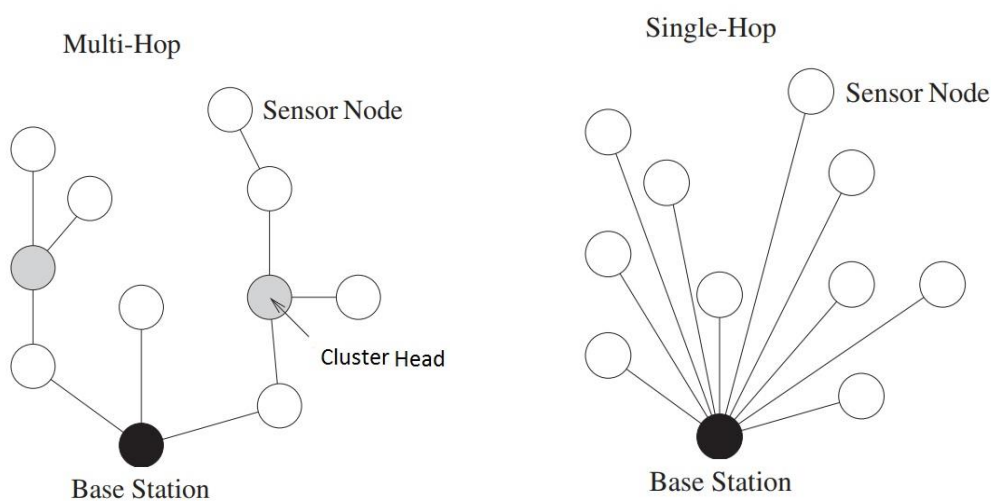


Figure 13 shows both multihop and single hop examples of WSN [14]

2.5.4 Flat network architecture and hierarchical network architecture

There are two types of architecture that can be implanted, these are known as flat network and hierarchical. The flat network architecture functions based off commands that are sent to all the sensor node, the sensor node that correlates with the query will respond to the base station with the requested data.

In a hierarchical architecture, a group of sensor nodes are gathered together to form a cluster, the head of that cluster is known as the cluster node, In this method, all the data is sent to the cluster head and then to the base station. [24]

IoT is an essential topic in this research paper. The research carried out highlighted the critical fundamentals of IoT and the ways of different implementations and possibilities that can be achieved with the use of IoT. IoT is a new concept that is going to become a common sight in everyday lives.

2.6 Conclusion for the literature review

To conclude this section of the research paper, the research topics have identified critical issues in relation to the need and creation of a temperature monitoring system. The essential highlights of the research are the effect of heat on semiconductors lifespan, Data centre design and cooling techniques and the ever-growing demand for networking services.

From the study it has identified the potential growth and need for more datacentre optimisation in relation to cooling and humidity control, other methods such as Microsoft's underwater data centres are still in the testing phases, but the investment from these significant companies clearly shows that there is a desire to further reduce the upkeep costs of the traditional data centre.

For further research, more emphasis on the study and understanding of the Arrhenius equation would help further the research and provide a better understanding of what is going on chemically, but for this project and discipline, the researcher felt it was best not to dive too far into the rabbit hole.

Chapter 3 – Research methodology

3.1 Introduction

This chapter will outline the research methods and the explanation of the research methodology implemented for the study of this topic. The approach of the research will be explained in detail, as well as the research design used. As there is a wide range of research topics available, there will provide a discussion about the chosen research methodology, along with an analysis of the advantages and disadvantages of the chosen research path.

3.2 Research overview

This section will explain the chosen research path based on three strategies. Following this design allows the user to clearly understand the research methods that need to be taken to carry out clear and relevant information for the topic of study. It provides an overview of the method selected and the reasoning for the chosen research. This has proven to be an excellent tool for researchers as it acts like a plan to help the researcher complete their goals set out by the aims and objectives set out.

The following table is the most commonly- used research strategies used for applied computing. There are other different ways of carrying out research, but this can be difficult to apply to such a project the text highlighted is the research methodology that is going to be taken for this research project.

Positivism			Phenomenology	
Deductive			Inductive	
Experiment	Software Development	Document Review	Case Study	Survey

Figure 14 shows the research process table

Philosophy of research

For the chosen research topic, the philosophy of the research needs to be based upon positivism. This means that the study and results are based upon the observation of an occurrence and provides the researcher with objective and statistical data. Positivism is the approach that is going to be taken with this research project as it allows for quantitative information that is required for this project.

Features of a positivistic approach to research

- The research method enables the use of larger sample sizes.
- Data is mathematical, specific, and precise.

- Reliability of the data is high
- The validity of the information is low

A Phenomenology approach to research would not apply to this project since that collected in this study would be subjective and is mainly used in social studies that examine thoughts and feelings to get results. This relies on data collection methods such as case studies, interviews, and surveys because this data is collected from another person instead of peer review, this would result in the collection of qualitative data.

Features of a phenomenological approach

- Data sample sizes tend to be smaller
- The data is mostly subjective
- Reliability of the information is low
- The validity of the data is high

3.3 Approach of research

The research approach for the paper will be deductive. The process of carving out a deductive path to research entails that there is a developed theory and hypothesis. Upon the creation of a hypothesis, there will be a research strategy to test that hypothesis that has been put in place.

3.3.1 Strategies

The project will take multiple different while following the core features of the positivism research methodology. This research project will take a mixed approach of experimental, software development and document review. This was required to collect the type of data needed for the research.

3.3.2 Document review

Documents review is the most crucial part of any project, using a document review, the researcher can understand any previous research that has occurred and finds information that is related to the topic of study.

The aims of a document review are to;

- Study and identify and main theories in the chosen field of research
- Understand any positive and negative impacts that might have a hindrance on the researchers' project
- Ensure that the selected project is relevant and practical for its current use case.
- Provide and support findings that match the results

3.3.4 Experiments

Experiments are used to get results and examine the relationship between two or more factors or variables. Whilst changing a single variable, the research can measure the changed from the other variables to get clear and concise results.

An experimental project must contain the following practices.

- Hypothesis
 - A statement in the form of a question must be created and clearly written in a phrased and testable format. By doing this, the researcher can carry out an experiment to provide an answer to a question.
- Experimental Variables
 - The variables are the factors that the researcher needs to investigate. There are two main types of variables that need to be considered. The independent variable and the dependent variable
 - The independent variable (IV) is going to be the variable that is going to be manipulated to get results. In the case of this project, it is going to be a measurement of workload placed on a given system
 - The dependent variable (DV) is the variable that is going to be measured. The result of the DV will be changed, but the influence and manipulation of the IV.

3.3.5 Software development

Software development as a strategy is vital to applied computing projects. Within this project software development will be used to create a database system and IOT system. Developing these two systems will allow the researcher the chance to carry out the experimental side of the project. The implementation of a novel software solution allows the researcher to collect the exact data that is needed to produce the results.

3.4 Finding credible research

The collection of quantitative data will be the focus throughout the research process. In order to successfully achieve this and receive excellent and insightful data, there will be a credibility strategies to ensure that the research meets the following criteria in order to be useful for the research project.

- Reliability
 - Reliability of research is essential in the project; Ways to check the reliability of any study is to cross-reference any figures and/or statements. There is also the consideration as if the test were to be carried out correctly to provide proper scientific results. In other words, if a specific test was to be rerun using the same variables, would it be repeatable. This will allow the researcher to accurately find out if the data is correct and is suitable to use within the project.
- Validity
 - For the validity of the research, there needs to be a process of making sure that the investigation is necessary and relevant to the topic. This will ensure that any data that has been collected from the document review can be used in a correct and proper manner.
- Generalisability
 - Generalisability is another consideration that has less impact on this research topic. In a typical case, this would be used to analyse the data and understand if the result applies globally or not. It got to be important that data is collected from the same business sector, to avoid any confusion while collecting the data.

Chapter 4 – Design and Implementation

4.1 Introduction

This chapter will be focusing on the design and the implementation of the identified issues and the proposed solution. There will be detailed sections to explain the choice of components with extensive justification for every step of the design and development process. This project involves the use of C, Mysql and PHP.

4.2 Identified issues and Proposed solution

There are a couple of Identified issues that need to be understood to create a solution. Firstly, heat and humidity influence semiconductor lifespan, this can result in higher failure rates of datacentre devices. Contaminants such as dust and dirt can reduce the cooling performance of devices by blocking the intake fans of the devices and causing operation temperatures to rise.

The proposed solution is to create an IoT monitoring system that would data log the intake and exhaust temperatures of devices as well as monitoring the temperature around the room and venting ducts over a specified period. From this, the data centre management team would be able to identify any concentration of heat within the racks of the data centre and carry out maintenance or relocate the servers to distribute the heat more evenly.

To create the IoT monitoring solution, there will be a need for the creation of sensor nodes, communication, and database. The nature of this system should allow for the continuous monitoring and reporting of the temperature and humidity.

4.3 The initial design of the system

Below you can find an initial draft of the proposed design, Using a (SOC system on chip) it is going to form a hierarchical network design that has a main cluster head controlling the flow of data to the database.

This design consists of 8 SOC devices and one database server, which in this example is a laptop. In this initial design, the following assumptions were made. The devices connected to each other using the 802.11n standard for wireless communication, The devices are going to be battery-powered, and the cluster head device is going to act as a wireless host for the other devices to connect too in order to form the network.

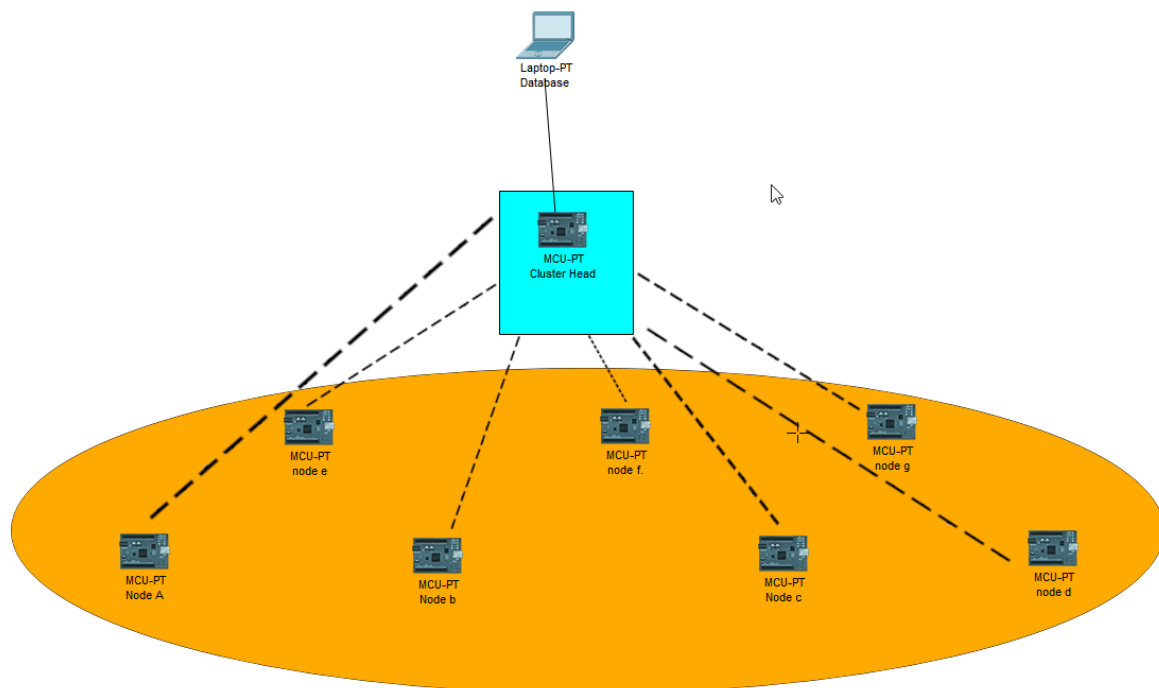


Figure 13 shows the initial design

Device components

For the creation of the sensors nodes, there is a couple of consideration on what type of components are required to create the sensor node. There are four elements that make up a sensing node. The Sensing Unit, processing unit and communications unit. This section is going to highlight the choice of components as well as the justification for each of the parts.

SOC (system on chip)

For the main computing element of the sensor nodes and cluster head, it was decided to use the Nodemcu esp8266 v3. The justification for this device is the main down to the full range of supported components. This gave the research a lot of options when choosing the fit for purpose sensing unit; another reason is that it has an integrated communications unit that supports 802.11n, This allowed the researcher to gain access to a lot of software support due to its popularity. The node MCU is like an Arduino as it uses the same software and same programming language

4.3.1 The sensing unit

For the selection of the sensing unit, the device had to be compatible with the node MCU since the node MCU functions the same as an Arduino with slight minor differences, the selection of components could be made choosing Arduino components. This required a look at the system requirements, and The sensing unit must be able to operate at 110c or above, this temperature is based to some typical thermal limits that computer components such a CPU (centralised processing units) are able to run to before forcing itself to shut down. The minimum temperature must be 18c or lower.

This is due to data centres do never operate below ambient temperature, by doing so could lead to condensation build-up, which in turn can increase humidity. Lastly, the sensor needs to be able to measure the amount of moisture in the air on a percentage scale.

To find the best sensing unit for the purpose was tricky because of the vast range of available components. For this task, a comparison table was drawn, in the table are the choice of components with meet the previously set requirements.

Comparing arduino sensors				
Name	Lowest Temp	Highest Temp	Accuracy	Cost
DS18820	-55	125	0.5	9.99
TPA81	4	100	2	0
MLX90614ESF	-40	85	0.5	4.23
DHT22	-40	80	0.5	3.25
Thermocouple I	-100	500	2	4.98
SHT21	-40	125	0.3	3.87
DHT11	0	50	2	2.79
D6T	0	50	1.5	2.49
LM75	-55	125	2	3.19
TMP100	-55	125	2	0
LM35DZ	0	100	0.6	2.3
SHT15	-40	123.8	0.3	3.99

Figure 14 is a comparison table of the different temperature monitoring sensors

In the table, there are the listings for the lowest and highest measuring temperature as well as the accuracy. From the comparison table, it shows that the best performing sensor in terms of highest and lowest temperature is the thermal couple, although this is an impressive specification wise it would be a bit overkill to implement it into the system. The best performing sensor based on accuracy is the SHT15 with an accuracy of 0.3+-c this was the initial choice for the system.

Upon purchasing the SHT15, it proved impossible to find any stock that was available in the UK. This is important just increase the sensors had some issues I was able to get a replacement quickly in order not to hinder the progress of the project. The SHT15 is also an older variation of the SHT sensor family, so the next choice for the sensing unit was the SHT21. This sensor still has proper specifications and work correctly for the implementation.

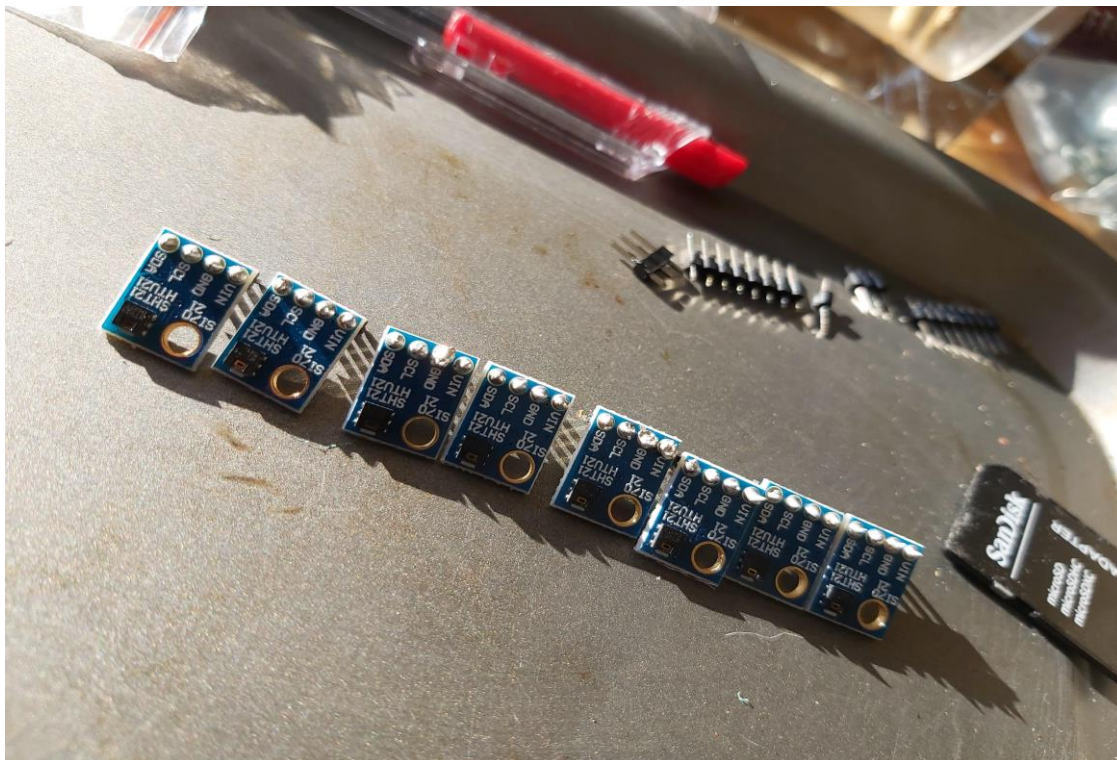


Figure 15 is a picture taken of the SHT21 sensors after being assembled and soldered

4.3.2 Other components and price

With the purchase of the Nodemcu and the SHT21 temperature, there also needed to be some extra components in order to make the devices functional, these include Node MCU baseboards, 9v Battery cases, 9v Batteries and Arduino cables. The components were ordered in advance from AliExpress based in china. This allowed the researcher to get the best price for the components. Here is the following cost for all the items required for the system.

NodeMCU x8 = \$23.87

9V battery Cases x8 = \$7.81

Baseboards x8 =\$22.56

Arduino cables x1 =\$3.25

Shipping = \$12.85

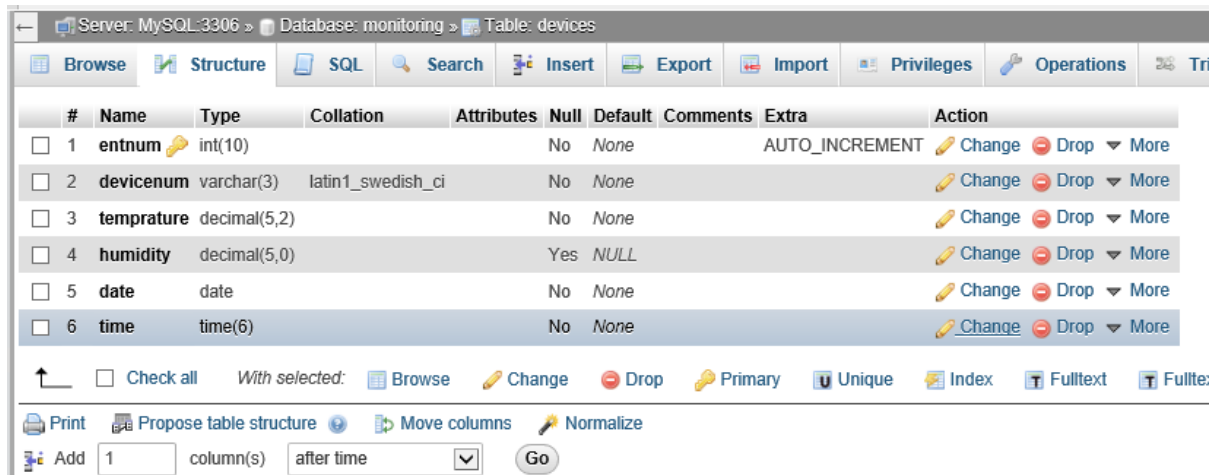
Total \$70.44 at the time of purchase this was equivalent of £54.32

4.3.3 Database

The requirements for the database are as of follows, it must be able to collect, and store information based upon the temperature humidity and the sensor identifier. The database

must then attach a date and time stamp to the row to be able to monitor the temperature and humidity over time.

For this, the researcher is going to use PHP and MySQL to create import data into the database from the sensor nodes. Using a computer and a wamp server, the data will be sent across the wireless host and stored in the single table database. From the database, the user can then extract the information into a CSV format to create a graph plotting the temperature and humidity over time.



The screenshot shows the MySQL database structure for a table named 'devices'. The table has six columns: entnum (int(10), primary key, auto-increment), devicenum (varchar(3)), temprature (decimal(5,2)), humidity (decimal(5,0)), date (date), and time (time(6)). The interface includes tabs for Browse, Structure, SQL, Search, Insert, Export, Import, Privileges, and Operations. Below the table structure, there are options to check all, browse, change, drop, primary, unique, index, fulltext, and fulltext. At the bottom, there is a section for adding columns, with '1' in the 'Add' field, 'column(s)' in the 'column(s)' field, and 'after time' in the 'after' dropdown menu.

#	Name	Type	Collation	Attributes	Null	Default	Comments	Extra	Action
1	entnum	int(10)			No	None		AUTO_INCREMENT	Change Drop More
2	devicenum	varchar(3)	latin1_swedish_ci		No	None			Change Drop More
3	temprature	decimal(5,2)			No	None			Change Drop More
4	humidity	decimal(5,0)			Yes	NULL			Change Drop More
5	date	date			No	None			Change Drop More
6	time	time(6)			No	None			Change Drop More

Figure 16 shows the structure of the implemented database

The image above is the structure of the database table. Each column is set up as the following. Entnum, Devicenum, Temperature, Humidity, Date, and time. The column identified as entnum assigns a primary key identifier to each piece of data that is received in an auto-incremented fashion.

Device number identifies the device that the data sent by. This is important to clearly identify where the heat and humidity issue is coming from. The assumption of the design is that each sensor will have its own unique number and will be placed around the data centre in a numerical format. This will make it easier to identify where there are issues if any occur in relation to temperature and humidity.

The temperature and humidity store the information in a decimal format to .2 decimal. By doing this, the data can show any slow and incremental trends in the temperature over time.

Finally, there is a date and time stamp associated with the data; When the data is received by the server, it assigns a date and timestamp. This is required to plot the graph over time.

4.4 Revised design

During the creation of the system using a nodemcu as a wireless host was proving to become a challenge. Constant miscommunication issues were happening between the sensor nodes and the database. After a couple of hours of research into the matter, the results bared many different solutions that did not fix the issue. After hooking up the sensors to the network in the home, it started to store the data in the database.

Researching into this issue a little more revealed that the Nodemcu board that was purchased turned out to be a clone of the original, and finding documentation for the cloned

nodemcu proved very difficult as there are so many different variations of the device. To resolve this issue, the researcher decided to purchase a wireless access point to act as an interface for the sensor nodes to be connected to.

This required the purchase of Cisco AIR-LAP1042N-E-K9 Aironet 802 Wireless Access Point, This device is an enterprise and is a bit overbuilt for the purpose of this product, but it was used on eBay for £20, and the researcher has previous experience with the Cisco CLI. This device should be able to support around anywhere from 1 to 250 wireless devices subject to bandwidth.

In order to power the access point, it requires PoE (Power over Ethernet), so the purchase of a PoE switch that would support the power requirements of the access point. The choice was the TP-Link TL-SF1005P 5-Port 10/100 Mbps Ethernet PoE Switch. This device is a plug and lay option that does not require a configuration. This cost at the time £28.48

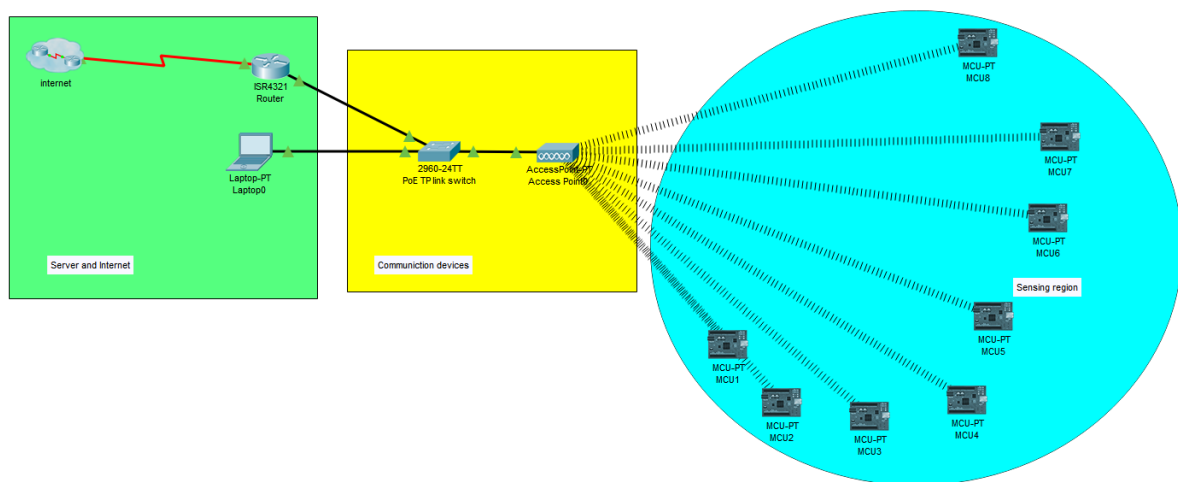


Figure 17 depicts the new proposed design for the implementation

In this new design [figure 17] there the communication devices have changed to the access point and the switch. These require constant power unlike the previous implementation, and this means that there is less chance of loss of data due to a battery running out of the main cluster head. For this testing purpose, only one cluster is going to be created and implemented as this is just an early prototype of the system, the system now has the capacity for expandability and scalability with the implementation of the switch. This will likely be the best approach for any further work on this topic.

What also has changed on this design is the sensor nodes are no longer battery-powered; instead, they will be powered by a USB power strip that will apply a constant power to the devices. While developing the system, the sensors were reporting the inaccurate numbers. When the battery gets below a certain voltage, there wasn't enough charge to maintain the proper use of the device, which then led to data being missing from the database. As this application is a static WSN, it would be better to have the devices powered continuously without the need to continually change the batteries which last around three days of constant use in low power mode.

In a full-scale system, each device in the data centre will have a sensor next to the exhaust of the equipment and sensors would be placed in adequate spots around the room and in the venting systems. This would provide enough data to plot the whole room and identify any hotspots and humidity issues.

This will give reliability to the system, and therefore allow it to collect accurate and consistent data.

Chapter 5 – Testing and evaluation

5.1 Introduction

The aim of this chapter is to show the results of the implementation of the system. To test this system, the research requested access to UWTSD server room in order to set up the system and carry out a short term data collection test on the temperature and the humidity of the devices and the surrounding ambient air. This testing would be left to run over the course of a week to get enough results to measure the effectiveness of the system, and possibly identify any concentrations of heat and humidity

5.2 Methodology

The testing will be carried out in the UWTSD server room. The room is designed as a simple server room with hot and cold aisles. This is good for the system because it can show the effectiveness of cold and warm air mixing in certain points in the room and identify any areas that are not getting adequate cooling.

The room uses an air conditioning unit and an exhaust vent which will be useful to measure the effect that the devices have on the air and the resulting heat. This room only contains a couple of racks which is suitable for the number of sensors that are being used for the implementation.

During the testing, the room is closed mostly closed, and only certain individuals have access to the room. This will show up in the results as the ambient temperature from outside the room will leak in from the door being opened, this will be reflected in the data and can be ruled out to avoid any inconsistent data mixing in with the final results.

- Observations that can be made,
 - when are the peak load times and could cooling be reduced at these times to save energy?
 - Are there any hotspots in the room that are causing the unnecessary build-up of heat?
 - Is the humidity of the room staying consistent, therefore reducing the chance of static shock?
 - Does any of the equipment require maintenance due to a blocked filter or other overheating issues

5.3 Coronavirus and the effect on this project

In March, the coronavirus started to affect everyday lives. The government was strongly recommending that everyone stay at home to avoid the spread of the virus. At the same time, the researcher was in contact with Anthony Daniels who is a part of the UWTSD IT management team and was organising the go-ahead for the system to be tested in the UWTSD server room. On the 13th of March permission was granted but the staff of busy working on a

contingency plan that would allow faculty and students access to the IT services of the University, so testing was delayed by a week until that was over.

On the 23rd of March 2020, the government of the United Kingdom announced a nationwide lockdown, which causes education, businesses, and social events to close down. In light of these events, the researcher has spoken to Dr John Rees, their supervisor. John suggested that it was too late to change the approach of the project that has been developed over the past couple of months. It was not viable to look at creating a simulation using computational fluid dynamics. This result in a lack of testing of the system in its proper manner to measure the effectiveness.

5.4 Testing and evaluation

The system works and is fully functional, but without access to the server room of the university, the data that was collected from preliminary testing does not suffice to fully evaluate its effectiveness. Instead, this section will focus on the conclusions of journals focusing on the thermal analysis of the datacentre using computational fluid dynamics and the conclusion that were drawn from the testing. The following article [28] discussed the thermal analysis of a data centre. The simulation is designed to predict the air temperature and adapt the amount of airflow based upon the workload, by doing this the result would be minimising the use of the air conditioning units and therefore reducing the operation costs. Here are the conclusions that were drawn from that research

- *“The average temperature on the rack surface at the cold aisle side is 15°C.*
- *The temperature at the cold aisle is varying from 12 to 17°C.*
- *The average temperature on the rack surface at the hot aisle side is 27°C.*
- *The temperature in the hot aisle is varying from 18°C to 32°C.*
- *The simulation shows that a good number of servers are experiencing temperatures well above and below the ASHRAE recommended temperature levels.*
- *Short-circuiting of cold air is clearly visible in the simulation.*
- *Using Computational Fluid Dynamics, the system was designed to reduce the capital cost of the data centre design by 10% of the original design.”*

The results show that the use of computational fluid dynamics it managed to reduce the cost of operation by 10%. This result is concurrent with another journal published by MDPI [27].

The code for the sensors, C and PHP programming for the original IOT monitoring design can be found in appendix 1 for reference. Also, in Appendix 2 is the first figures from the test that was run to test the IoT system before its implementation in March.

Chapter 6 – Conclusions, recommendations, and reflections

6.1 Conclusion

The conclusion for this project is that it requires further testing for the original IOT system, due to the experiment being postponed at mid-March. Judging from the research, there is a growing appetite for the need for better monitoring of data centre and improvement of existing designs. Computational fluid dynamics is a great tool that would benefit this project greatly if it were to be taken any further.

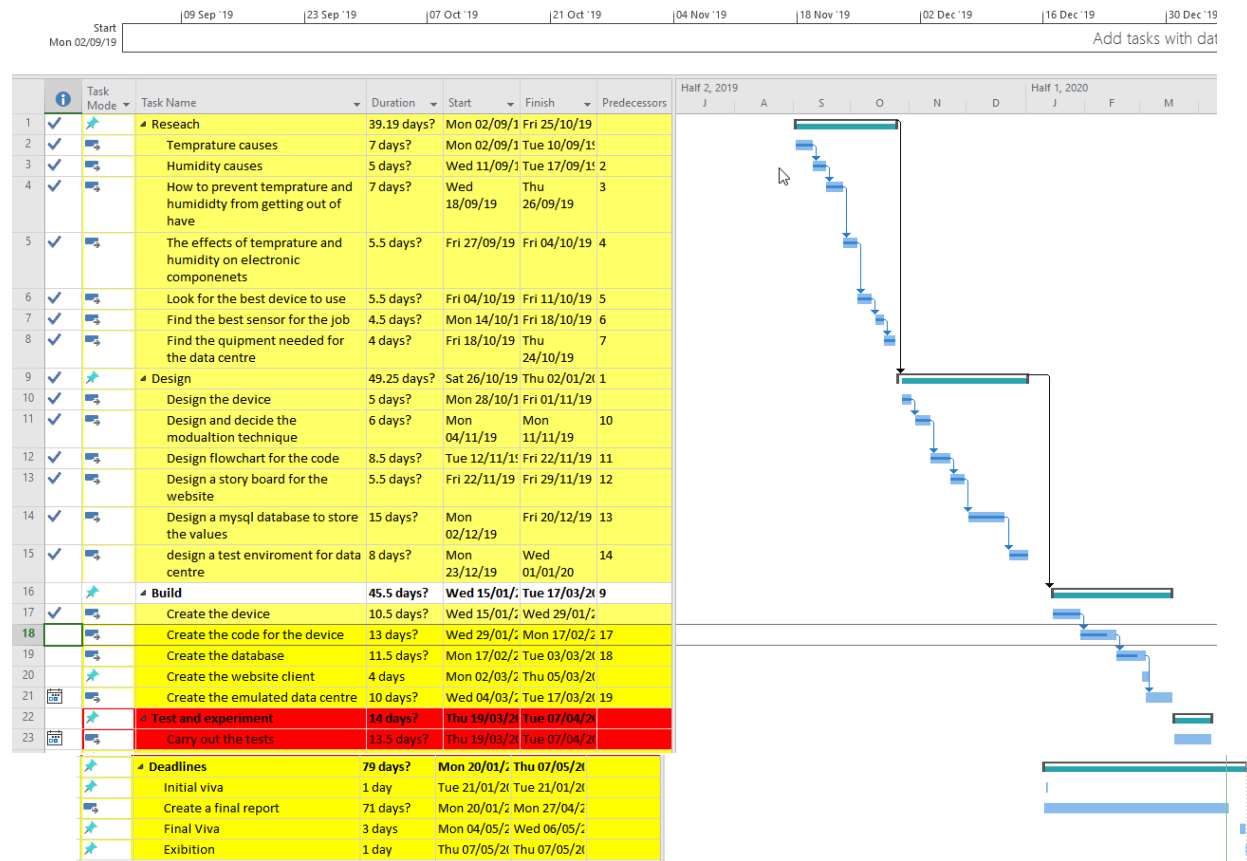
The information that would have been collected from the system could be implemented into a simulation tool for CFD. This would provide an excellent visual representation of what the temperature was over time and help visually identify any low load times where the energy-saving measures could come into play.

Therefore, if this project was to be taken and developed, there need to be more sensor nodes to implement into the server room to provide a wider variety of data. An API interface could be a significant benefit to usability to the end-user and would require a team of software developers that would need to be outsourced.

The answer to the hypothesis stated at the start of the paper “Can the use of IoT help reduce the cost of operating a data centre?”. The answer is yes, it can. IoT has a wide variety of applications, this project being just one of them. It is one of the biggest growing engineering trends in the past decade; hopefully, the further adoption and investment of IoT will shape the future to come and make an impact on everyone’s lives. By making little improvements such as reducing energy consumption can make a big difference not only finically, I can also reduce the impact on the natural environment, and that is the real goal.

Chapter 7 – Project planning

From the start of this project, the researcher has been creating a project plan to show the progress along the way and the task that need to be completed. This is to actively improve their time management and achieve the goal of this project. This was done by keeping meeting notes with supervisors and producing a Gantt chart.



The field highlighted in red were not able to be completed due to the global pandemic.

Chapter 8 – References

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Appendix 1

```
sensorpost$  
#include <ESP8266WiFi.h>  
#include <WiFiClient.h>  
#include <ESP8266WebServer.h>  
#include <ESP8266HTTPClient.h>  
#include <Wire.h>  
#include "SHT21.h"  
SHT21 SHT21;  
  
const char *ssid = "testap"; //wifi settings  
const char *password = "loll2345678";  
  
//post too  
const char *host = "192.168.1.17";  
  
//power up  
void setup() {  
  delay(1000);  
  Serial.begin(115200);  
  WiFi.mode(WIFI_OFF);      //Prevents reconnection issue  
  delay(1000);  
  WiFi.mode(WIFI_STA);      //This line hides the viewing of ESP as wifi hotspot  
  
  WiFi.begin(ssid, password); //Connect to your WiFi router  
  Serial.println("");  
  
  Serial.print("Connecting");  
  // Wait for connection  
  while (WiFi.status() != WL_CONNECTED) {  
    delay(500);  
    Serial.print(".");  
  }  
  
  //If connection successful show IP address in serial monitor  
  Serial.println("");  
  Serial.print("Connected to ");  
  Serial.println(ssid);  
  Serial.print("IP address: ");  
  Serial.println(WiFi.localIP()); //IP address assigned to your ESP  
  
  SHT21.begin();  
}
```

```

//Program loop
void loop() {
  float humidityres, tempratureres;
  String devicenum, temprature, humidity, postData;

  humidityres = (SHT21.getHumidity());
  tempratureres = (SHT21.getTemperature());
  temprature =String(tempratureres);
  humidity = String(humidityres);
  devicenum = "A";

  HTTPClient http;    //Declare object of class HTTPClient

  // postData = "dl=" + devicenum + "&tl=" + temprature;
  http.begin("http://192.168.1.17/post.php");//Specify request destination
  http.addHeader("Content-Type", "application/x-www-form-urlencoded");

  int httpCode = http.POST("dl=" + devicenum + "&tl=" + temprature);    //Send the request
  String payload = http.getString();    //Get the response payload

  Serial.println(postData);
  Serial.println(httpCode);    //Print HTTP return code
  Serial.println(payload);    //Print request response payload

  http.end();    //Close connection

  delay(50000);    //Post Data at every 50 seconds
}
//=====

```

```

<?php

$servername = "localhost";
$username = "root";
$password = "";
$dbname = "monitoring";

// Create connection
$conn = new mysqli($servername, $username, $password, $dbname);
// Check connection
if ($conn->connect_error) {
    die("Database Connection failed: " . $conn->connect_error);
    echo "no connection";
}
print_r($_POST);
//Get current date and time
date_default_timezone_set('GMT');
$d = date("Y-m-d");
//echo " Date:".$d."<BR>";
//echo $_POST;
$t = date("H:i:s");
echo "hello";

if(!empty($_POST['d1']) && !empty($_POST['t1'])) //&& !empty($_POST['h1']))
{
    $devicenum = $_POST['d1'];
    $temprature = $_POST['t1'];
    $humidity = $_POST['h1'];

    $sql = "INSERT INTO devices (devicenum, temprature, date, time)
VALUES ('".$_devicenum."', '".$_temprature."', '".$_d."', '".$_t."')";
    echo "hello";
    if ($conn->query($sql) === TRUE) {
        echo "OK";
    } else {
        echo "Error: " . $sql . "<br>" . $conn->error;
    }
}
else
{
    echo "no data";
}

$conn->close();
?>

```

Appendix 2

	A	B	C	D	E
1	entnum;"devicenum";"temprature";"humidity";"date";"time"				
2	1;"A";"23.00";NULL;"2020-03-15";"16:56:10.000000"				
3	2;"A";"23.00";NULL;"2020-03-15";"16:56:15.000000"				
4	3;"A";"23.00";NULL;"2020-03-15";"16:56:20.000000"				
5	4;"A";"23.00";NULL;"2020-03-15";"16:56:25.000000"				
6	5;"A";"23.00";NULL;"2020-03-15";"16:56:31.000000"				
7	6;"A";"23.00";NULL;"2020-03-15";"16:56:36.000000"				
8	7;"A";"23.00";NULL;"2020-03-15";"16:56:42.000000"				
9	8;"A";"23.00";NULL;"2020-03-15";"16:56:47.000000"				
10	9;"A";"23.00";NULL;"2020-03-15";"16:56:52.000000"				
11	10;"A";"23.00";NULL;"2020-03-15";"16:56:58.000000"				
12	11;"A";"23.00";NULL;"2020-03-15";"16:57:03.000000"				
13	12;"A";"23.00";NULL;"2020-03-15";"16:57:08.000000"				
14	13;"A";"23.00";NULL;"2020-03-15";"16:57:14.000000"				
15	14;"A";"23.00";NULL;"2020-03-15";"16:57:19.000000"				
16	15;"A";"23.00";NULL;"2020-03-15";"16:57:25.000000"				
17	16;"A";"23.00";NULL;"2020-03-15";"16:57:30.000000"				
18	17;"A";"23.00";NULL;"2020-03-15";"16:58:01.000000"				
19	18;"A";"23.00";NULL;"2020-03-15";"16:58:51.000000"				
20	19;"A";"23.00";NULL;"2020-03-15";"16:59:41.000000"				
21	20;"A";"23.00";NULL;"2020-03-15";"17:00:32.000000"				
22	21;"A";"23.00";NULL;"2020-03-15";"17:01:22.000000"				
23	22;"A";"23.01";NULL;"2020-03-15";"17:02:12.000000"				
24	23;"A";"23.09";NULL;"2020-03-15";"17:03:02.000000"				
25	24;"A";"23.15";NULL;"2020-03-15";"17:03:53.000000"				
26	25;"A";"23.15";NULL;"2020-03-15";"17:04:44.000000"				
27	26;"A";"23.17";NULL;"2020-03-15";"17:05:34.000000"				
28	27;"A";"23.13";NULL;"2020-03-15";"17:06:25.000000"				
29	28;"A";"23.09";NULL;"2020-03-15";"17:07:15.000000"				
30	29;"A";"23.07";NULL;"2020-03-15";"17:08:05.000000"				
31	30;"A";"23.06";NULL;"2020-03-15";"17:08:55.000000"				
32	31;"A";"23.08";NULL;"2020-03-15";"17:11:36.000000"				
33	32;"A";"23.18";NULL;"2020-03-15";"17:12:27.000000"				
34	33;"A";"23.11";NULL;"2020-03-15";"17:13:17.000000"				
35	34;"A";"23.05";NULL;"2020-03-15";"17:14:07.000000"				
36	35;"A";"22.99";NULL;"2020-03-15";"17:14:57.000000"				
37	36;"A";"22.98";NULL;"2020-03-15";"17:15:48.000000"				
38	37;"A";"22.96";NULL;"2020-03-15";"17:16:38.000000"				
39					