REAL-TIME SCOREBOARD PROJECT ASSESSMENT

Feasibility Study

1ST AUGUST

R&D STUDENTS
AUT

Team Members:

Hayley-Belle Cleverdon
Vinicius Alves Ferreira
Karanjit Gahunia
Seung-Kyu Jin
Alex Lu

Client:

Dr Robin Hankin

Supervisor(s):

Nikola Kasabov
Akshay Raj Gollahalli

Moderator:

Dr Stephen Thorpe

Version:

Feasibility Study Version 1.0

Table of Contents

Project Description

This project is a Research and Development project assigned by the Computing and Information Sciences Faculty of Auckland University of Technology (AUT). Dr Robin Hankin, a lecturer at AUT, proposed the project on behalf of the Auckland Mathematics Association (AMA), who are key stakeholders in the project.

Dr Hankin has asked that we provide an in-depth feasibility study and a presentable prototype for a real-time online scoreboard to be used during MATHEX events run by the AMA. This scoreboard would be used alongside the current pen-and-paper system, and aims to improve the experience that audience members have during the event, by allowing them to view the scores of each team as the competition is underway.

The feasibility study, along with all other project documentation, should provide enough information that another group of students could carry on with the project at a later date. The prototype can be presented to AUT as evidence of our development skills, as well as provide a working version of the solution for the AMA's consideration.

Project Overview

Project Objective

Our project objective is to create and implement a Real Time Online Scoreboard System into the Casio MATHEX competition within 1 year with a budget of $20,000.

Project Scope

Our project scope has two major sections. The first section aims to produce a feasibility report which investigates whether the production and implementation of the scoreboard within the one year time frame is achievable. If the feasibility report reveals that the project cannot be completed in a year, then we will produce a Project Roadmap which details the project processes and tasks necessary to design, create and implement the scoreboard successfully into the MATHEX competition in case of project hand off.

The second section aims to produce the hardware and software for the Real Time Online Scoreboard system. This system will improve the attendee and participant's experience by making it easier to keep track of the competition's scores, as well as streamline the judging process. Initially, a prototype for the system will be produced which will attempt to showcase and incorporate as many of the client's requirements as possible.

Technical Assessment

This assessment aims to inform and advise the client (as well as future teams undertaking this project, if this is the case) of the technical needs and solutions for the project under discussion.

This assessment consists of an analysis of 3 main areas:

1. The venue's infrastructure and existing hardware.
2. The hardware solution evaluation.
3. The cloud based solution evaluation.

Lastly, a recommendation is given based on the information presented in each section. It aims to address the best solution to the problem domain.

Venue Infrastructure

Note that most of the information in this report was obtained on a visit to the ASB Stadium by Karanjit Gahunia on the 30th of June, 2017. Brian Tomlinson, the general manager of ASB Stadium, was interviewed during this visit. The findings are based on the interview as well as observations made on this visit. Photos were taken during this visit and Mr Tomlinson has given permission to use those photos in this report.

Venue Information

Venue Size

The Auckland MATHEX events are held at the ASB Stadium in Kohimarama. The main gym is used for this event which spans over 2 days, with 2 sessions each day. The main gym floor is 45m × 30m (1350 sq/m) and has a floor above with seating for approximately 3500 people. In previous MATHEX events, there have been approximately 5000 people in attendance each day (between the 2 sessions). The amount of people attending these events has been increasing.

Unused Seating Section

The layout of MATHEX competitions at ASB Stadium can be seen in figure 1. In previous years, the seating section behind the markers has been completely closed off (figure 2). This is to prevent spectators from cheating by seeing the answer sheets that the markers have. However, in recent years, higher rows of seating have been opened due to high attendance at these events.

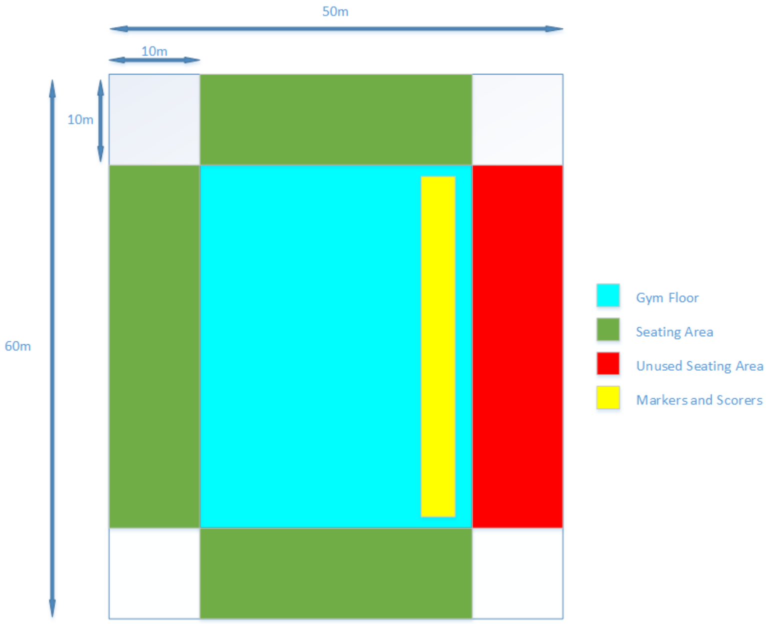

Figure 1. MATHEX competition layout at ASB Stadium

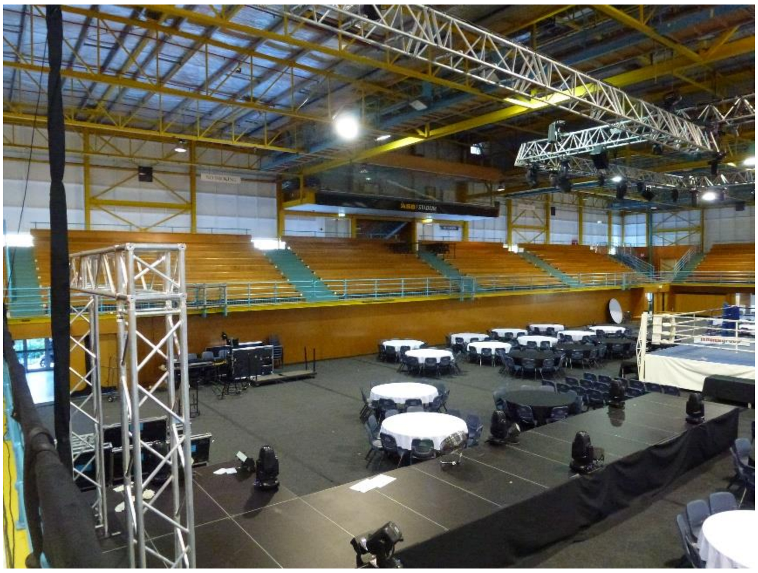

Figure 2. Unused seating section during MATHEX

Networks

Overview

There are 2 Wi-Fi networks installed in the main gym area of ASB Stadium. The first network belongs to the stadium itself whereas the second network belongs to Selwyn College. Both networks have one access point each installed in the main gym (figure 3). According to Mr Tomlinson, both networks can potentially cover the entire main gym area.

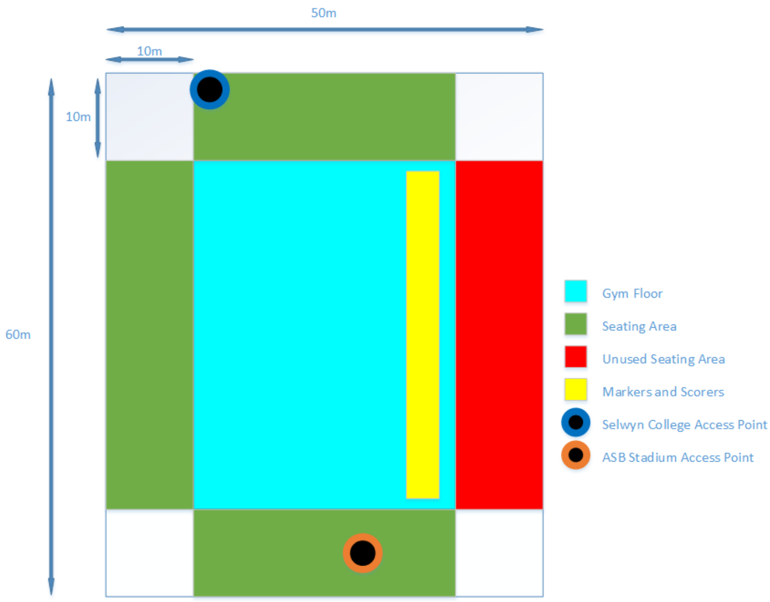

Figure 3. Location of Access Points in the main gym

ASB Stadium network

The ASB Stadium network is a broadband internet network. The access point is located under the seating area. There are other access points located in the stadium that are also connected to this network (e.g. reception area). A speed test of the network showed that the connection had 17 ping, 15 Mb/s download, and 12 Mb/s upload. Mr Tomlinson says that adding repeaters would extend the range to cover the main gym area. The stadium is open to us bringing our own equipment to install and utilise along with their network.

Selwyn College network

The Selwyn College network is a fibre internet network. There is one access point installed in the main gym area (figure 4). Permission to utilise the network would have to be requested from the Maths department of Selwyn College. There is no speed test data for this network.

Figure 4. Access Point for the Selwyn College Wi-Fi network

Existing Equipment

Scoreboard Display

There is no projector screen or other type of display installed in the main gym area. However, there is plenty of space to install a temporary screen and projector for a big scoreboard display. Mr Tomlinson recommends using a space in the unused seating section (figure 5) as it has been used in the past for similar uses. This location would be visible from most spots for spectators as well as competitors in the MATHEX competitions.

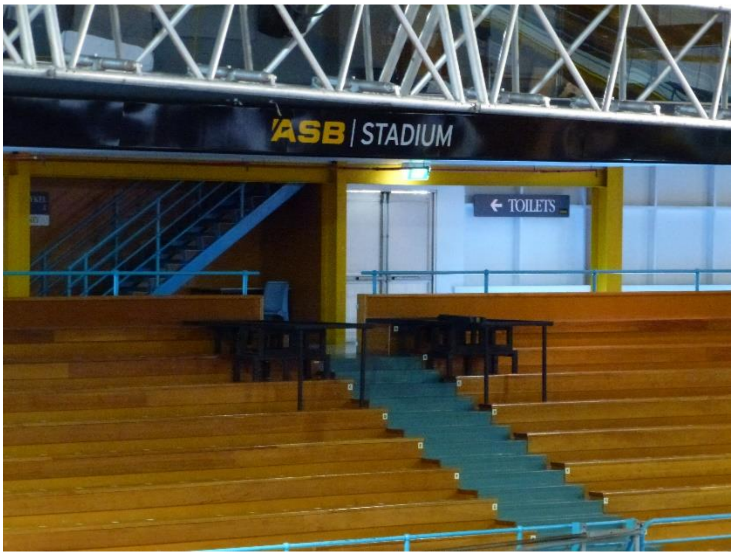

Figure 5. Recommended location for display

Network and Server Equipment

There is no existing equipment such as access points, wireless repeaters, or servers that could be used for the Real-Time Scoreboard System implementation at the stadium.

Further Research Areas

Some of the areas that require further research include:

- The capacity and range of access points installed in the main gym.
- The type of equipment (if required) for extending the existing networks.
- Permission regarding the use of the Selwyn College network.
- Speed of the Selwyn College network.

Hardware requirements

This section aims to evaluate the hardware necessary in order to host the application in a local environment. As there are many options available, our goal is to recommend adequate hardware to satisfy the client's needs.

It is crucial to understand that this research was undertaken as an individual component of the project, and it disregards any information about the venue's current infrastructure such as networking or non-physical solutions, like a cloud-based system.

Any pricing provided was acquired through the research process on May 23, 2017, all prices are subject to change.

The research was done based on the requirements of the system, see below:

- Project goal is to create a **real-time** scoreboard application or website.
- Can handle approximately 100 users (markers) updating the database simultaneously.
- Can handle at least 400 users (spectators) or requests simultaneously.
- OS was not specified as client required an open source system. AUT could also provide assistance with software.

Please see <u>appendix A</u> for *hardware specifications and quotation and <u>appendix C</u> for definitions.*

Solution 1

To host a back-end system for either a web-based-application or mobile phone application we recommend the system be divided into three servers: Reverse Proxy Server, Application Server, and Database server (please see figure 6 for a high-level network draft). For reliability and performance, it is recommended that you separate them (Elmasri & Navathe, 2000).

The use of a reverse proxy server would, among many other benefits, distribute the load from incoming requests. It will also protect against common web-based attacks such as DoS, DDoS, and malware. Additionally, it would reduce the load on its origin servers by caching static content.

The application server would be responsible for handling requests from the user or proxy server. It would inquire the database and provide results to the users, as well as handle all processing for each request.

The database is responsible for managing and storing all data of the application, and serving it back to the application server when requested.

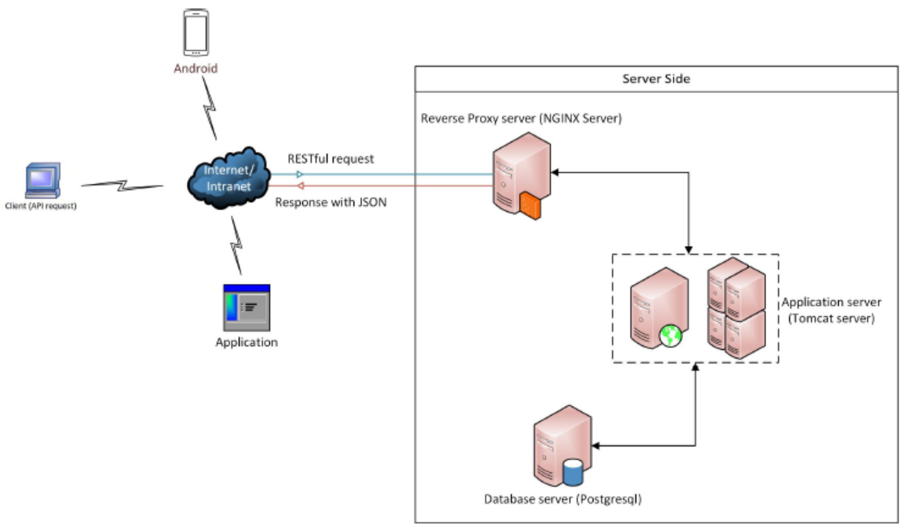

Figure 6. Discussed Framework

Solution 2

A more compact solution that would also impact on the cost of the system is to utilise virtualization (Portnoy, 2016). The use of this strategy would allow us to co-populate two servers on one host. Essentially this means that one server would fulfil the role of two. In this case, the application server and the reverse proxy server will be in one server. This strategy eliminates the need of one of the three servers mentioned in solution 1. However, some enhancements could be required, such as a higher RAM capacity.

Beyond the cost benefits, using virtualization is a more efficient use of the processing power of a server. Taking into consideration that most of the requests will be I/O bound rather than CPU bound, the hardware recommended would not have issues with the demand (Buelta, 2017).

However, there is consequential reliability on the server in discussion, creating greater risks. For the same reason, we recommend that the database server is a separate system.

Solution 3

A simpler approach is to have one server that works as a database and application server, to eliminate the need for a proxy server. This is common practice for small applications or businesses.

This approach has several issues though such as slowness, no response at all, security issues, and a much higher risk of the entire system crashing. Therefore, we discourage this solution until the criticality of the system is fully assessed. System failure could lead to a major disruption in the competition.

Hardware specifications

There is no simple or exact way to predict performance and scalability of a system. Each application and the environment it operates in is different. Programming languages, programs, Application Programming Interfaces (APIs), and functionalities all require a different amount of memory, processing power, internet bandwidth, and other resources as it also behaves differently.

The most accurate way to determine the correct specifications for a server or servers is to measure performance which will require the application itself or a prototype application to create a testing environment (Oracle, n.d.). Tests can be performed using virtual servers, load testing applications like "JMeter" (http://jmeter.apache.org), and application performance management tools, for instance AppDynamics or DynaTrace, to measure performance and identify bottlenecks. Only then, we can estimate what hardware specifications will suffice, without building an overzealous and unnecessary system (Subraya, 2006).

For now, we have estimated what we believe would be required for the application to run and satisfy the requirements. However, these are only estimates.

Attention: prices are subject to change based on the parts' brand, type, quantity. There are several ways to achieve the same or similar specifications.

See Appendix C for definitions.

Recommended Server Specifications:

Database Server

HDD - 2 TB or more SSD enterprise grade in RAID set-up.
Processor - Intel Xenon processor that support Error Correct Code (ECC).
128 Gb (minimum) with ECC.

Reverse Proxy Server

HDD - 1 TB or more SSD enterprise grade in RAID set-up.
Two or more processors - Intel Xenon processor that support Error Correct Code (ECC).
128 Gb (minimum) with ECC.

Application Server

HDD - 1 TB or more SSD enterprise grade in RAID set-up.
Two or more processors - Intel Xenon processor that support Error Correct Code (ECC).
128 Gb (minimum) with ECC.

Note: these estimations above were provided by "Akshay Raj Gollahalli".

Quote for Server Specifications:

Database Server

2x Intel Xeon E5-2620 v4 2.1GHz Processor, 8Core/16Thread (Supports ECC)
8x 16GB (128GB)of Memory RAM (ECC Registered)
Hardware RAID controller with 2GB flash backed write cache
2x 150GB SSD (RAID1 – OS/Boot only – 150GB Raw usable)
6x 960GB SSD (RAID10 – Database – 2.8TB Raw usable)
Write workload max: 3.6TB per day

Reverse Proxy Server

2x Intel Xeon E5-2620 v4 2.1GHz Processor, 8Core/16Thread (Supports ECC)
8x 16GB (128GB)of Memory RAM (ECC Registered)
Hardware RAID controller with 2GB flash backed write cache
2x 150GB SSD (RAID1 – OS/Boot only – 150GB Raw usable)
6x 480GB SSD (RAID10 – Hot Data – 1.4TB Raw usable)
Write workload max: 1.8TB per day

Application Server

2x Intel Xeon E5-2620 v4 2.1GHz Processor, 8Core/16Thread (Supports ECC)
8x 16GB (128GB)of Memory RAM (ECC Registered)
Hardware RAID controller with 2GB flash backed write cache
2x 150GB SSD (RAID1 – OS/Boot only – 150GB Raw usable)
6x 480GB SSD (RAID10 – Hot Data – 1.4TB Raw usable)
Write workload max: 1.8TB per day

We believe that the specifications of the servers quoted for are more than sufficient to satisfy the requirements, whilst also providing scalability for the future. However, due to the frequency of the MATHEX competitions, we recommend to purchase only hardware that will be used.

The requirements listed in the "Hardware Requirements" section and the recommendation provided above were used to inquiry for a quote. Our retail contact assumed that this is an enterprise-scale application, inferring that the servers will be running continuously with a constant 500 users or more. Therefore, the amount of storage memory is significantly high, it uses 2 processors and the memory matches the recommendations. This is why the specifications are so high for the servers.

See appendix A for the full description.

What we think will be necessary:

When assessing the current requirements, clearly there is not a significant amount of data that requires storage. For this reason, the database queries will be fast and simple. Also, the application should not perform complicated tasks that require heavy usage of the CPU. The challenge at hand is the hundreds of users using the application concurrently. Due to the powerful hardware available in the market, we believe that one server (Solution 3, see Hardware Requirements) should suffice.

Application Server \ Database Server

1x Intel Xeon E5-2620 v4 2.1GHz Processor, 8Core/16Thread (Supports ECC)
4x 16GB (64GB)of Memory RAM (ECC Registered)
1x 150GB SSD (OS/Boot only – No RAID solution provided)
2x 960GB SSD (RAID1 – 960GB Raw usable)
(Excluded) ~~Hardware RAID controller with 2GB flash backed write cache~~
(Exchanged) ~~Supermicro 1028R-WC1RT Barebone~~

In this estimation, we have replaced the barebones as only one CPU is needed. Note there are four extra slots for memory to provide scalability. Also, excluded the CacheVault Supercapacitor as its extra protection is not necessary at this point.

Using this estimation, extra servers could be purchased to comply with the other solutions highlighted previously in the Hardware Requirements section. If this is the case, the specification above can be manipulated to reduce costs and adjust to the needs of the system application.

See appendix A for the full description.

Additional costs:

Some other equipment may be necessary such as:

- Racks or cabinets to hold the servers
- UPS (Uninterruptible Power Supply)

Other Elements of an in-house Implementation

Along with acquiring the adequate hardware to satisfy the current requirements, there are other components which require attention. In many cases these are considered the drawbacks of purchasing your own hardware.

Failure management - Disaster management

It is important to plan for any events that may occur and affect the system performance. These events can include; hardware faults, power outage, system overheating, and any natural disaster. Therefore, a disaster or recovery management plan would be necessary. However, such plans are usually the responsibility of the client to develop, this depends on whether the client determines that the information is vital, and that creating the plan is a necessity. The plan must also comply to the venue's health and safety policies.

Common solutions are to have:

- Servers kept in a temperature monitored room.
- Fire suppression system in the event of a fire.
- A generator that kicks in automatically to supply power to the servers during an outage.
- Back-up servers to take place when one stops working and daily back-ups of data.

The list goes on, but these are the most significant regulations (Air Intelligence, n.d.).

In the case of MATHEX competition, the current paper-pen system would not be discarded as the last resort back-up plan.

Maintenance

It includes regular hardware and software checks, to ensure the system is up to date and working as intended. The system may also undergo updates for bug fixes and adding features. Maintenance may also be extended to other parts of the system, such as the options mentioned in the failure management section above (Swanson & Dans, 2000).

Cost of running the equipment

We assume that the servers and its peripheral devices will not be located at the venue and will need to be moved from place to place, which will also infer set-up costs and tests. Maintenance of the system will also generate costs as well as possible hardware faults.

Durability

A computer also has a lifespan, which is usually estimated between 3 to 5 years, but it is subjective. It will depend on how it is used, how often it is used, and how it is maintained. There are many systems in existence that have been running for several years and will likely still live for many to come with the appropriate maintenance. However, replacement of parts is to be expected, which will incur further costs (Swanson & Dans, 2000).

Cloud Solutions

We have reached the conclusion that there are two different approaches we can take for a cloud-based solution for this project.

The first is a series of static web pages for all necessary components of the system. This includes; a small database and two or more webpages. The small database, consisting of one or two tables will store data. A user will access a web page which will send a request to the server, which pulls data from the database and displays it on the webpage. The markers will also be using a web page, but instead they will be sending requests for the server to transfer data into the database. To add security to the system, there is the option to include a login page for judges, otherwise they can be given a generated URL to access the pages privately.

This solution requires that data about the competition is collected, such as what teams and students who are participating. It may also be necessary to generate login credentials for judges to keep the database secure.

Technologies used for this solution are expected to be as follows:

- Amazon S3: Web hosting.
- Cloudflare: Web security and optimisation.
- Amazon RDS: Database Engine
- Languages Used: PostgreSQL, HTML and JavaScript OR Java (run on a Tomcat servlet).

The second solution would be to develop an application that displays on the web, this application would need to have the same capabilities of the first, but it would also include ways for administrators to set up competitions. This application will take up significantly more data on the cloud server, but it will also be a dynamic way to set up competitions, as the front end will provide controls to create custom leader boards.

Technologies used for this solution are expected to be as follows:

- Amazon EC2(T2): Web hosting
- Cloudflare: Web security and optimisation.
- Amazon RDS: Database Engine
- Languages Used: PostgreSQL, HTML and Java (run on a Tomcat servlet).

Web Hosting

Web hosting can be thought of as having a high-tech computer, with a huge amount of storage space and processing power, all available through an internet browser. In reality, the web host already has all the necessary (and very powerful) hardware, they're just letting you use it for a small price, and providing an interface for you to control it.

A web application is stored with the web host, and set up with a domain so that users can access the system. From there the web host handles all the data, requests and runs the software as it was designed. This solution is reliable, easily accessible and low-maintenance (Hilvert, Moore & Bradley, 2003).

Amazon

Amazon is a powerful and cost effective solution to web-hosting. It provides more computing power than any other online service and is completely free to join.

Amazon only charges for what you use, so setting up a small website will only cost cents per year.

S3 stands for Simple Storage Service. It provides an object storage to host cloud-based applications, websites, repositories and much more. It is designed to be fully scalable, boasts durability, a 99.99% uptime, easy to manage and fully integrated with a wide range of Amazon's other web services.

EC2 provides a very similar service, but acts as a remote computer that can run software. EC2 is geared towards running applications, so the processing happens on Amazon's side, rather than the user's internet connection.

RDS is Amazon's leading relational database system, it is a simple way to implement a database into an existing Amazon service and utilise it. A small database is free.

Amazon's web services are unique because they are distributed worldwide, so users around the globe can access sites with improved latency. They are also unique due to their dynamic scaling – as soon as more storage or processing power is used, that is what you are charged for. Rather than most web-hosting services, which require you purchase the amount you need, and if you need more you must buy a set amount, and if you don't use it all, well that's just too bad because you've already paid for it.

All this information and more can be located at Amazon Web Services' web site. (https://aws.amazon.com).

Cloudflare

Cloudflare is like a virtual router for websites. It is a proxy server that filters malicious visitors, saves bandwidth and accelerates user connection to the website. Best of all, for a small website with low needs, Cloudflare is totally free!

Cloudflare increases the speed of a user's connection by routing based on the user's location, connecting them to the nearest datacentre in their location. Cloudflare also caches data on your website (temporary storage) so that when a user is loading up a page with the same images and code scripts, the data is all waiting in Cloudflare, rather than needing to be requested from the web host once again.

Cloudflare also reads a visitor’s IP to determine whether they are a threat to your website. Any detect threats are screened from the site and have no access to the site’s bandwidth. Cloudflare provides all of this information and more (https://www.cloudflare.com).

Existing Solutions

There has been a demand for custom leader boards, though nothing significant. After some research we found two suitable pre-made solutions.

AirScoreboard (http://www.airscoreboard.com):

An iOS exclusive app, for an affordable $0.99US. This solution allows users to create and manage leader boards as well as share them to various social media sites. It has a few additional features such as locations, languages, posters, and it has a way for ‘athletes’ to register themselves. A lot of these features are more than what is needed for the MATHEX scoreboard, and the iOS-only limitation is a large barrier.

Rise (https://www.rise.global/pages/simple):

This site offers a large variety of leader boards, at what appears to be a commercial standard. It portrays itself as a visually-polished application and is available on web, mobile or on-screen (presumably one with ‘smart’ capabilities). While this is a great solution, there are no metrics to measure its reliability or security, it is not clear on the site whether they are using another web hosting service or have their own. Should this solution be explored, further information should be gather from a representative of Rise for this information before making a decision. There is an undeniably larger cost involved, at 14.99GPB (up to 100 teams) or 29.99GBP (up to 300 teams) per month. Though, it would only need to be up and running one month out of the year.

Estimated Costs

Assumptions:

- 400 audience users, each making about 50 requests from the database over the competition duration.
- 100 markers, each making 100 requests to the database over the competition duration.
- Total storage of 500Mb or less.
- Data transfer in/out at 100MB/1GB per month at most.

Solution	*Monthly Cost**	*Yearly/Total Cost**
Solution 1	$0.21	$0.37 (per year)
Solution 2	$3.33	$12.41 (per year)
AirScoreboard	$0.00	$140.89 (total – for 100 devices)
Rise	$27.65	$27.65 (yearly, by cancelling after 1 month)

** Currency converted to NZD 25/05/17 – this does not include conversion charges.*

Note that these costs only account for the running costs. There might be additional costs such as electricity, internet, hardware (for the network and devices for markers), etc. Those costs are difficult to estimate since they largely depend on other factors such as how the system is implemented.

Solution Summary

The most feasible choice here is Solution 1 – a simple set of static web pages hosted on Amazon S3. Not only is this a cost-effective solution, that allows AUT to be branded alongside the AMA to encourage learning in New Zealand, it is highly achievable.

A simple site will not take an extended period to get up and running and ready for testing. This is ideal to ensure that the client gets to see an early prototype and have input on design decisions. The prototype will have plenty of time to be user-tested and presented to stakeholders part of the AMA.

It will also be very easy to build upon a simple site, to a full application in future, as the design decisions will have already been made.

Next up is between Rise and Solution 2. Both are supplying the same kind of functionality. However, Rise robs our group of the opportunity to develop anything, which we're very keen to do. Solution 2, the Java application, will take some time to build, and may not have much time for testing. It is likely the prototype will be very basic and lacking a few features.

Solution 2 will be ideal to explore after the prototype of Solution 1 has been fully tested, it is unlikely that this will be undertaken by our group, unless outside of the Research and Development paper – the source code will always be available for anybody to build upon should they wish to.

Lastly, AirScoreboard is barely worth mentioning. It has a lot of ‘fun’ features, that are not necessary for the commissioned system, and it being a paid app exclusive to iOS puts massive limitations on it. The judges would each need to have an iOS device to log scores, which is not at all feasible.

System Implementation

The Infrastructure

Based on the current state of the venue, it is expected that additional equipment will be required to provide access to the wireless local area network for all MATHEX attendees. Both existing networks at the stadium have just one access point in the main gym area. More access points and repeaters would be needed to extend the range and capacity of the networks to accommodate for the MATHEX competition attendees. Moreover, depending on the choice of application solution and system implementation, the existing internet connections may not have sufficient bandwidth to handle the amount of traffic. In this case, solutions with the internet service provider will need to be explored. Note, that this will likely be at the expense of the venue for any potential upgrades.

On the other hand, there is also the option of internet access through the user's own data plan, which will be at their own cost. This isn’t ideal as only a limited number of users would be able to access the system. This is only applicable for a cloud based approach.

As a reminder, because the MATHEX event could take place in different venues in the future, the full assessment of the venue is not our main focus.

Purchasing the Hardware

The benefit of having all the servers at the same location where the MATHEX event occurs is that there is no need for internet access. The presence of a Wireless Local Area Network (WLAN) would satisfy the needs to run the application and connect all the users present at the event.

However, the equipment costs can be very high. There are also potential future costs such as: the set-up of the system, transferring the server location, maintainability and labour. Additionally, a disaster management plan may be required to comply with venue's policies and general health and safety regulations, as well as to keep the data backed up and stored, and keep the competition running.

MATHEX events are infrequent. As we understand, those servers and any other equipment would not be used for the rest of the year which would could lead to waste of resources. The equipment will also need to be stored at someone’s expense, and be insured if it is damaged, misappropriated, or lost for any reason.

The MATHEX events seem to be increasing in popularity and attendance each year. It may not always be feasible to accommodate for all users present at the event as the hardware would have limited scalability. It may require new hardware components or servers, replacements of old parts, and new technology. To conclude, adding more capabilities to the system reapplies all the risks of implementing the system in the first place, costs will need to be calculated each time and will most definitely increase.

Therefore, we believe that purchasing and maintaining your own servers for this particular solution is not cost effective and is a misuse of resources.

Using Cloud Solutions

Using a cloud solution will require internet access, which means the internet bandwidth must support the traffic of data otherwise users will experience slowness when using the application.

There are different cloud services available, but many of them allow you to pay as you go, meaning you are only charged for what you use. With this feature, there is a significant reduction in costs, as the application and the resources necessary can be reserved whenever they are needed and paid accordingly. Furthermore, it eliminates any need or concern for servers. Their location, status, storage, maintenance, and all other concerns listed above are of no consequence to the developers, client, venue, or any other stakeholders. The companies that provide these services are responsible for their hardware and software.

In case the number of users increases, more resources can be purchased with ease. In some cases, cloud providers may adapt automatically and charge accordingly.

It is evident that using a cloud service will be significantly cheaper than purchasing your own hardware. It will eliminate many headaches, and can be used at any place and time as long access to internet is available.

Note: It could be of the client’s wishes to purchase the hardware, if they are not readily available in AUT. The same system could be maintained at AUT's grounds and be provided over the internet. This approach would work over the internet similarly to the Cloud approach.

Recommendation

After our assessment, we have concluded that the best option for the implementation of an application that satisfies the client's requirements and reduces both short and long term costs, is the use of cloud technologies.

This does not imply that Cloud services are more advantageous than having your own hardware, but for this specific project, the benefits of utilising cloud services outweighs the benefits of buying hardware.

We believe that the set-up of the servers will be complex, and therefore, we cannot commit to the reliability of the system. On the contrary, using a system already set up for us provides a higher chance of success.

Application Solutions

In this section, we would like to emphasize potential applications which aim to fulfil the project scope. We concentrate our discussion on what they are, and why or why not they should be considered. We have identified three ways the application can be built; web-based application, mobile device application and a computer application. We list them below.

Web-Based application:

What:

It is an application which runs in a web browser.

Why:

Because any computer or mobile device, using any operating system can access and use the application provided there is access to the internet (or the network where the app is hosted) and a web-browser capable to surf the internet. This is the most universal and accessible approach compatible to all devices.

Mobile phone application:

What:

It is an application that runs on mobile devices, smart-phones or tablets.

Why:

The great majority of people have at least one type of mobile device in New Zealand. A mobile phone application is often more user-friendly and optimised for smart devices.

Why Not:

There are several types of mobile phones and tablets, this increases the complexity of creating an application, particularly where operating systems are concerned. The most common ones are Android, iOS and Windows and therefore supporting all operating systems may not be feasible.

Furthermore, to use an application on a mobile device it must be downloaded and installed first. The size of an application varies, but when any download is involved a user will typically avoid doing so on their data plan, and opt to download on WiFi. To download the application, users must have access to the internet or download it before coming to the MATHEX competition. Otherwise, having hundreds of people downloading at the same time using the same network will result in the network becoming slow, hence generating delays for the scoreboard system.

Lastly, because uploading the app to the device’s respective app store would incur additional fees, it will need to be downloaded from an unauthorised location, which many users may not trust.

Computer application (Physical Scoreboard):

What:

A desktop application that runs in a computer. This approach would not be available to the spectators but only to the markers so the answers can be entered. The score board would be mirrored to a screen(s) through a projector or monitor positioned such that spectators can view the scoreboard.

Why:

The aim of this solution is simplicity. It would reduce significantly the amount of resources needed such as powerful servers, internet access and Wi-Fi connection for spectators. Due to the low traffic of data, one computer could take over all the work that needs to be done (refer to solution 3 in the hardware requirements section).

Why Not:

There is a high risk that implementing a scoreboard using a projector will not solve the problem. It is possible the spectators will have problems seeing the screen's content. Also, only the top teams will be shown on the screen unless a different solution is provided. The most important part of this solution is setting up a projector or screen at the venue, which will incur costs and will need to be tested against safety regulations. At this stage, this approach does not add any considerable value to the MATHEX competition instead more complications.

Note: The application used by the judges to enter the answers is not defined here. It could be a mobile app, a web-page or another computer application.

The Application - Conclusion

Based on the assessment above, the Web-Based application solution is the best option that satisfy the project scope. It is simple to use and requires no installation for users. Also, it facilitates implementation due to its universal framework.

Operational Assessment

The operational assessment aims to cover and answer the following issues about the new system and its different approaches:

- **Process:** How the users will benefit from the new system and its processes. There are three main users: spectators, markers/scorers, and the judge. However, the focus will mainly be on the spectators, as different approaches do not affect other users.
- **Implementation**: How much time, cost and/or other resources each approach will use as well as their physical implementation in the competition's venue.
- **Evaluation**: Whether the system can work and cover key goals covered in the project scope.

Current System

The MATHEX competition currently uses a pen and paper system to track the scores of teams. This consists of a flow between a Marker, Scorer and Judge. Through communication with Gillian Frankcom-Burgess we have gained an understanding of how exactly the competition works.

A Runner will run with an answer from their team to the table. They will be assigned a Marker, there is approximately 60 markers in attendance, each responsible for up to two teams. A marker has a sheet in front of them with two marking tables, one for each team. The rows are for each question, one column is numbered to its respective question, and the adjacent column is blank to indicate how many points a team scores.
When a team answers a question correctly, they gain points for that question, and the Marker notes this on the table. The team can also pass on a question to move on to the next one. When either of these occurs, the Marker hands the Runner the next question to take to their team.

The Scorers are responsible for tallying the total score of each team, there are fewer Scorers, and they will be responsible for checking multiple Markers' sheets. The Scorers will post up the points underneath each teams' respective score area. For example, a School A has an area with their initials SCA, and underneath a piece of paper with their total points is pinned.

The Judge is responsible for ensuring everything is running smoothly, is the Scorers or Markers run into any issues, the Judge helps. The Judge also determines the winners, and relies on the Markers to notify them when a team is close to winning. A Marker should record the time that a team reaches 100 points to determine their placing in the competition.

Mobile Scoreboard

The original approach allows users to see a real-time scoreboard of the competition using their portable devices. It will use a custom server to allow users to connect to it and allow them to fetch and update information.

The cloud approach functions similarly to the original but uses the internet and cloud servers instead of a physical server.

Process

The spectators stand to see the most benefit from this approach. They will be able to search for and track specific teams as well as the rankings for the entire competition. While these approaches are the most beneficial to spectators, features such as tracking and sorting will be restricted to spectators with smart devices.

The cloud approach has similar benefits but is limited by the bandwidth and capacity of the networks located in the competition's venue.

Implementation

The cost of the server as well as the time it takes to develop the spectator and judge application makes this approach easily the most expensive. As for other issues with implementation such as the location of the server in the competition, these are almost negligible or easily mitigated.

The cloud approach significantly reduces the cost of the implementation. The limited bandwidth and capacity of the internet access points can be mitigated by the implementation of 4G/LTE modems in the venue.

Evaluation

The original approach solves the problem of spectators being unable to see the competitions standing. Furthermore, it allows the users to track specific teams. The system's hardware will be able to set up a local Wi-Fi network and should be able to set up the Real-Time Online Scoreboard from any location. However, the cost in resources is significant.

The cloud approach similarly solves the main problem of spectating the competition but may be hindered by technical issues. In addition, it can only be set up in an area with a somewhat strong internet connection. Overall, the main functionality of the system covers the main scope for spectators however it does not meet the requirements of readymade hardware capable of setting the system up without an internet connection.

Physical Scoreboard

This approach replaces the user connecting to a server to view a scoreboard on their devices and instead uses a physical live scoreboard that will be placed in view of the spectators at the venue.

Process

While the spectators will be able to see how teams are faring in the competition, the ability to track specific teams will be removed. It will also be more limited as not every team will be able to be shown due to size constraints. An additional component to automatically scroll through the scoreboard must be introduced to compensate. Furthermore, the scoreboard may affect teams of the competition. This approach, however does have an additional benefit in that all spectators will be able to view the scoreboard and is not limited to smart devices.

Implementation

Like the approaches above, there is a custom hardware or a cloud approach. The time and cost constraints are also similar. The hardware approach will cost much more to develop. The physical scoreboard's location and size may also be an issue.

The cloud approach costs less and because users do not have to connect to the access points in the stadium, this approach is less hampered by capacity and bandwidth issues. In addition to this, this approach will take significantly less time overall to develop as there will be less to develop for the spectator's side.

Evaluation

This approach does allow spectators to view the standings in the competition but specific team tracking must be accomplished by either waiting for the scoreboard to scroll or by searching the paper scores for a specific team. Depending on the approach, the system may also be able to be implemented into a hardware solution but the additional need for a physical screen hampers its portability. Overall, this approach has the least amount of benefits to the spectators compared to the other approach and only covers the basics of the scope. However, it is the most feasible of the approaches and takes the least amount of time and cost to develop and implement.

Legal Assessment

The legal assessment covers all the legal aspects of the project and aims to verify that the project meets government laws and safety standards. This study focuses on two specific areas: the ASB Stadium Sports Venue where the Casio MATHEX competition takes place and the Open Source Licenses that may be used in the project.

ASB Stadium Sports Venue

The stadium has its set of Terms and Conditions that must be closely adhered to. This section will focus on the most relevant terms and conditions to the project.

- "**10.5** The hirer will not make nor allow any alterations or additions to any part of the venue or install any electrical or mechanical device without first obtaining the approval of the ECCT."
- "**10.9.** Any electrical devices used at the Venue must comply with the appropriate standards. The hirer will indemnify the ECCT against any loses which occur as a result of the use of electrical equipment that does not meet the terms and conditions or the appropriate standards". (EECT Stadium General Terms and Conditions V2.0 (2017). *East City Community Trust Board*, Section 10: Use of the Venue)

This section means that approval will be necessary if modifications to the venue become crucial for the project to succeed. We will also need to make sure that all hardware meet safety standards and regulations. In addition to this:

- "**10.8.** The hire area must be reinstated by the hirer at its sole cost to at least the condition it was in immediately before the hire period. All reinstatement must be completed within the hire period after which time the ECCT reserves the right to complete reinstatement on the hirer's behalf and at the hirer's cost.". (EECT Stadium General Terms and Conditions V2.0 (2017). *East City Community Trust Board*, Section 10: Use of the Venue)

If modifications are made to the venue, then we will need to revert these changes after the competition is held. This could mean that significant costs could occur before every competition if it is necessary to modify the venue to implement the project.

The terms and conditions also state that any damage, loss, claim, cost, liability or expense will be our own responsibility should the project fail in any way.
(EECT Stadium General Terms and Conditions V2.0 (2017). *East City Community Trust Board*, Section 15: Exclusion of Liability)

EECT is the East City Community Trust Board. It is made up of three members mainly: Selwyn College (Ministry of Education), ASB Stadium Sports Club and the Community.

Licensing

For licensing, we have decided to choose the route of open source licensing rather than a closed source. This is because we want future teams to be able to access our work in the case the project cannot be completed by our team as per the client's requirements. When choosing an open source license there are several associated conditions that we must consider. There are many different licenses but for this legal study we will look at three of the most popular licenses; the MIT license, Apache License 2.0 and the GNU AGPLv3 (GitHub, n.d.).

The MIT license is one of the most permissive licenses with conditions only requiring preservation of copyright and license notices. Licensed works, modifications, and larger works may be distributed under different terms and without source code. This means you can re-use the code freely for your own use and use it for non-commercial and commercial re-distribution. You cannot however claim authorship of the software (GitHub, n.d.).

The Apache license 2.0 is like the MIT license but it has a few more restrictions. You can re-use the code freely for your own use, non-commercial and commercial distribution but the big difference is that you must state your changes made to the software and include a notice that the change has been made (GitHub, n.d.).

The GNU Affero General Public License (AGPLv3) is a strong copyleft license. Copyleft licenses require the derivative works or modified versions of existing software to be released under the same license which will ensure that all future modifications or versions of the software will follow the same conditions and have the same permissions. Additionally, per the full text of AGPLv3, this license is specifically designed to ensure cooperation within the community in case of network server software. As our project is a network server software, this will prevent problems where the software source code is not accessible due to being run on a server (GitHub, n.d.).

Recommendation

The MIT, Apache 2.0 and GNU AGPLv3 are all good licenses, the choice depending on how restrictive we want to be with the software. If we want to let anyone use our software and make changes as they see fit, then the MIT and Apache 2.0 licenses are good licenses to consider. If we want to put some more restrictions to our software and make sure that users follow our conditions, then the AGPLv3 is a good option.

Open Source Requirements

Since we are using Open Source licenses, our project will be subject to a few requirements and conditions to preserve the provenance and openness of the software being used. Listed below are the general conditions and limitations the project may have to follow:

- **“Disclose Source:** Source code must be made available and public for anyone to see.”
- **“License and Copyright notice:** A copy of the license and copyright notice must be included somewhere within the project code.”
- **“Warranty Limitations:** The license explicitly states that it does not come with warranty.”

(GitHub, n.d.)

Open source licenses also come with permissions which allows to do the following with the project:

- **“Commercial Use:** Allows us to use the project commercially.”
- **“Distribution:** Allows us to distribute the software to others.”

(GitHub, n.d.)

Resource and Schedule Assessment

Our schedule indicates there is a period of approximately three months to develop an application that meets the client's request. Throughout this period a prototype could be developed and tested along with the client's approval. By the time the application is ready to be tested in an appropriate test environment, there will be no MATHEX competition scheduled. Also, it is possible that the implementation system of choice may be unavailable.

Furthermore, it is important to evaluate the people who will continue to work on the project as they are the most valuable resource. There are several areas of knowledge involved in this project as mentioned on previous sections. Areas such as:

- Network infrastructure expertise
- Hardware knowledge and System specifications
- Performance and loading tests
- Knowledge on server's implementation and administration
- Software development

When looking at the current team responsible for the development of this project there is a considerable lack of experience and knowledge in these areas. The only identified area of knowledge within our team is software development. Essentially there is only so much the team will be able to learn in the given time span.

Within the time constraints of these project, it is not advisable to submit the team into such a challenging path. There have been multiple discoveries during the research phase which lead to changes in the initial requirements and estimations of time management. One example being that it was first stated that around 500 users would use the system concurrently when the actual number could reach over 2000 users. It is important that the system is thoroughly tested before it is implemented, so that a stable and satisfactory final product is produced.

Recommendation

Given the resource and schedule constraints, we recommend that the timeframe for the project is extended, and tasked to another team with more relevant knowledge areas. Given until the 2018 MATHEX competition, our team, or a more experienced team should complete the scoreboard as a final product.

Our team will be able to present a final version of the feasibility study, and a working prototype that can be tested against requirements and usability. We feel this is within our ability given the current resources and schedule.

Schedule

Our schedule for building a prototype:

Provisional Milestones	Finish
Stage 0	28/07/17
Plan - design of project model complete	28/07/17
Stage 1	11/08/17
Framework and Database setup complete	11/08/17
Stage 2	25/08/17
Website development complete	25/08/17
Stage 3	22/09/17
Website integration with database completed	22/09/17
Stage 4	06/10/17
Online Real Time Scoreboard implementation complete	06/10/17
Stage 5	20/10/17
Website UX\UI improvement complete	20/10/17
Handover Complete	27/10/17
Client feedback	29/09/17
Supervisor feedback	20/10/17
Poster	3/11/17
Reflective Report	3/11/17
Portfolio and Final Product	3/11/17

** Please see the complete Project plan for further details*

Risk and Recommendations

As suggested by Schwalbe (2014), our team conducted a brainstorm to identify the risks and issues that could be present in the solution for this project. Schwalbe lists several knowledge areas in the risks of an IT project, but we focused on areas that applied to implementation of the solution specifically

Costs

Budget is a major issue for this project. After speaking with Gillian Frankcom-Burgess, a MATHEX judge and organiser, it was clarified that AMA would not be able to provide any financial assistance for the system. The markers and scorers at the MATHEX competition are all volunteers, and the audience members and schools are not charged for their attendance. It is a non-profit event.

There is no free way to implement this system due to the following factors:

- All potential solutions require purchases of either hardware of software to operate.
- Setting up the system on the day requires labour time.
- Maintenance of the system requires labour time.
- Hardware or software failure will incur fees to replace them.
- Technically the development time also costs AUT money, and has already incurred costs within our team.

The project has been assigned $20,000. This amount is an estimation only provided by client. The whole project is expected to surpass the $20,000 budget, considering all potential costs. There may be a case where the costs will be minimized, but at this stage, we cannot make an accurate estimate. Our current estimations already surpass these costs, see Estimated Costs Incurred section in the project proposal for details.

Possible Solutions:

The system would require a sponsor to be completed. This could be the client, AUT, or an external source. Future costs could be covered by advertising within the system, however this may make the system less attractive and inconvenient to users. Also, considering how infrequently the system will be utilised, advertising would take a substantial amount of time to make a significant financial impact.

Users:

The users of this system potentially include audience members, markers and scorers. Information from Frankcom-Burgess (2017) gave us insight into who the markers and scorers are. They are volunteers, mostly consisting of teachers from attending schools, and are often older and unlikely to have much technical knowledge. She stated “many [markers] are a lot older than [Generation Y] and many of them do not have a smartphone”.

The MATHEX competition has been running since approximately 1980, and has not changed much since Frankcom-Burgess became involved in 2012. The pen and paper system is tried and true for the markers and scorers, and changing this system is unlikely to be received well initially.

On top of this, the markers and scorers are not picked early, and are unknown until the date of the competition. Frankcom-Burgess (2017) states "I don't know who [the markers] are going to be before they arrive". Training is brief because it is simple, there would not be any time to teach these users how to use the system without error.

Possible Solutions:

There are some alternative ways to implement the system that may aid in this problem. This is based around the availability of the system per user, and we explore this further in the following issues.

Rather than asking each marker to input the score for a team, we can ask the scorers to do this, and ask for compliance from AMA's end to organise who these scorers will be. A scorer is usually responsible for collecting the scores from multiple markers and so they could update the system.

Otherwise, an employed or volunteer single scorer who is well versed with the system could gain permission to attend the event and gather scores to update the leader boards.

Effect on event sentiment:

Audience members currently watch the competitors' race across the venue to run their scores. While we haven't all witnessed the event in person, videos and descriptions of the event would infer it is an exciting event to watch.

In a situation where a system for the spectators' personal devices is implemented, rather than watching the competition before them, parents and other audience members will be spending time looking at their phones, hence more detached from the competition itself.

Although the innate problem is the confusion of who is winning the competition, the thrill and mystery of this will be eliminated by this solution's implementation. Therefore, it may not necessarily be beneficial to introduce.

Possible Solutions:

While the client initially suggested allowing spectators to have the leader boards on their personal devices, it is possible to set up a projector or screen in the event venue instead. This way the spectators are still seeing over the main event, much like at any sports or music event, the screens are there to compliment, rather than replace the atmosphere.

Distraction to competitors

This refers directly to the solution supplied above. A large screen in the venue is may cause distraction for the competitors. Where normally they would be focused on the math questions that they are given, there would now be a large leader board in full view for them. When students have their performance monitored and compared to other groups, it can impact their performance. Ark (2016) describes this issue, with the criticism that it may be a detriment to students that are struggling and favours the students who are excelling. The competitors are kids, younger than 13. The competition is supposed to be a fun experience rather than a source of stress.

Possible Solutions:

Instead of installing a screen, only allow the spectators see the scores so that there is no longer a distraction for the competitors. We are aware that this solution directly contradicts the previous solution, this is a major dilemma and a significant contributing factor to the project's infeasibility.

Suboptimal infrastructure available

As outlined in the study in the section "Existing Equipment" in Venue Infrastructure, there is little available infrastructure for a system to be installed. Hardware would need to be supplied to boost the signal from one, or potentially two access points. We do not believe the network here is aimed at supplying sustained connectivity to 500 or more concurrent users.
At this moment, we are unsure whether there is suitable space for a local network or any hardware to be set up. Further inspection of the venue is required here.

Possible Solutions:

We can put in a request for the venue to upgrade their infrastructure and hope for the best in that regard. Alternatively, we can ask that spectators use their own data to access the scoreboard, there may be issues with service providers in this respect, but it takes responsibility away from the venue or AMA to maintain a connection for them. The Wi-Fi will exclusively be for the scorers or markers using the scoreboard solution. Having a local network set up also solves this issue. However, this hardware will be very costly to purchase.

Health & Safety

When introducing any hardware into a venue at any event, there are always health and safety concerns. All electrical equipment introduces a potential fire hazard, more details about this are outlined in the Disaster Management section of the hardware requirements. Affixing a screen to anywhere in the stadium also presents a risk, it needs to be stable and not fall and potentially harm anyone attending the event.

Possible Solutions:

Options here are to create a Disaster Management plan and gain approval from the venue when the system is ready. The risk here being that all equipment is purchased and is then deemed unsafe. Using a cloud solution bypasses many of these issues, as the only hardware required is personal devices.

System Failure

Regardless of the solution selected, there is always a risk of system failure. Hardware systems pose more of a threat because they require hands-on maintenance from the hardware owners, ensuring they are updated, backed-up, secure, cleaned, and kept cool and dry (eBay, 2016). Even then, hardware has a life-expectancy and will need to be replaced or upgraded to avoid failure due to wear and tear, and in doing so this can also be the root cause of an outage (Zhu, Mauro, & Pramanick, 2003).

With a software solution, if bugs may arise, it is the developers' responsibility to handle these kinds of errors. However, in cases where the system has a third-party host, it relies on their maintenance to keep it up and running. Occasionally these services go down, or stop offering their services for various reasons. Such as; the service growing too complex, becoming obsolete, or maintenance becoming too difficult (Kajko-Mattsson, 2001). The developer will need to have a back-up plan ready for these situations.

Possible Solutions:

Careful maintenance of hardware will be required to avoid system failure. This will come at a cost to whomever the hardware owner is. Software failure can be prevented with scheduled testing and by having a backup server provider in case the chosen one becomes unavailable. Selecting a good server provider helps avoid this issue too, and any concerns can be resolved by contacting the provider directly.

Marketability

As stated previously, the competition has already been running for numerous years, using the same pen and paper scoring system. This works well for the markers, scorers and judge, and there is no need for them to replace it or introduce a system that makes the process more complex.

At this point we have little evidence to show that implementing the system is a necessity to the spectators. To our understanding, the members of the audience almost exclusively are parents of the competitors, whom we infer are there to support their children, rather than track which teams are in the lead. But we understand that it would still be a nice thing to know how the competition is unfolding.

Frankcom-Burgess (2017) explained that while she felt the system was not entirely necessary, a weak point in the system is knowing when a team is about to win and getting an accurate timing on when that team won. Even with this in consideration, we would be hard-pressed to convince AMA to implement the system "The competition is low-key" and "It's just meant for us" are among statements from Frankcom-Burgess (2017).

Possible Solutions:

The scoreboard was suggested with the spectators in mind, so these are the people we need to get in touch with to ascertain whether this is a system they would like to see implemented. Seeing as the next MATHEX competition is not too far away, we could hand out surveys at the end to parents, or interview them and ask for their opinion and give a short description of what they could see at the next MATHEX competition. If they support it, it may convince the organisers to work with us to reach a realistic solution.

To further convince AMA that our system is worth their time, redefining the scope should be considered. AMA is responsible for the competition, and will be able to inform of all stakeholders involved and highlight their needs.

This project could be further extended to solve the client's problem as well as the problems in the MATHEX competition. For instance, registering schools and students to the competition could be moved into a more efficient system, rather than via email.

Conclusion

The full assessment of our study points out that the Real-Time Online Scoreboard System is not feasible at this point. To elaborate, we do not believe that the proposed system can realistically meet current schedule, resource and cost restraints. There are also far too many issues related to implementation, even upon completion the Real-Time Online Scoreboard is more than likely to be rejected by AMA.

To proceed with the implementation of the Real-Time Online Scoreboard System, the team must focus on defining and understanding the scope. It will need to gather more requirements from different stakeholders and present them to our client for approval. Simultaneously, the team must develop an application that satisfies each new requirement.

To broaden the scope of the project, this will incur further costs, a longer schedule and upskilling or introduction of experienced developers. However, taking the time to do this gives the project a chance to be successful. Attempting to only release a scoreboard, even disregarding cost, schedule and resource limitations, is very likely to fail.

Next Steps

Due to the requirements of the Research and Development paper, our recommended next step is to create a prototype. We plan to create the leaderboard display, as we have identified this as the secondary key deliverable for the client, after this Feasibility Study. This leaderboard prototype should display all the functionality that will be used during the competition.

We will seek confirmation that requirements are being met, first through paper prototyping for design, and then with a web application for functionality. This application prototype can then be improved upon request. There will be no need for the client to acquire any of the implementation solutions to see the software demonstration, as no dedicated hardware or third-party software is required. This allows time for the project to be further expanded, and the client can further analyse his options.

Further steps will be to gather requirements and recommendations from all MATHEX stakeholders, to determine the direction of the scope. Once this is complete, a new proposal should be created and the feasibility can be re-evaluated.

Our team expects to have developed a software prototype at minimum, but will endeavour to take as many of these steps as possible within our schedule restraints.

References

Images

Figure 1 - Retrieved from: Feedback 1. Author: Akshay Raj Gollahalli. 10th April, 2017.

Citations

Air Intelligence (n.d.) *Computer Room Air conditioning / Server Room Design & Build.* Retrieved 22 July, 2017, from http://www.airintelligence.co.uk/computer-rooms/

Ark, T. V. (2016). *To Leaderboard or Not: The Art of Motivating and Monitoring* Performance. Retrieved from http://www.gettingsmart.com/2016/03/to-leaderboard-or-not-the-art-of-motivating-and-monitoring-performance/

Buelta, V. (2017). Requests per second. A server load reference. Wrong Side of Memphis. Available at: https://wrongsideofmemphis.wordpress.com/2013/10/21/requests-per-second-a-reference/

eBay (2016). *How to Properly Maintain a Server (and Minimize Downtime!)*. Retrieved August 4, 2017, from http://www.ebay.com/gds/How-to-Properly-Maintain-a-Server-and-Minimize-Downtime-/10000000177629547/g.html

EECT Stadium General Terms and Conditions V2.0 (2017). *East City Community Trust Board.* Retrieved from http://www.asbstadium.co.nz/uploads/4/7/4/6/47460497/eect_stadium_general_terms_and_condition_v2.pdf

Elmasri, R., & Navathe, S. B. (2000). Fundamentals of Database Systems

En.wikipedia.org. (2017). Multitier architecture. Available at: https://en.wikipedia.org/wiki/Multitier_architecture#Three-tier_architecture

GitHub (n.d). *Licenses | Choose a License*, Retrieved August 2, 2017, from https://choosealicense.com/licenses/

Hilvert, J., Moore, P., & Bradley, H. (2003). Choosing a Web hosting service. *Australian PC User*, *15*(4), 108.

Kajko-Mattsson, M. (2001). Can we learn anything from hardware preventive maintenance? *Engineering of Complex Computer Systems, 2001. Proceedings. Seventh IEEE International Conference on* (pp. 106-111). IEEE.

Oracle (n.d.) *Determining Hardware Capacity Requirements.* Retrieved 10 July, 2017, from https://docs.oracle.com/cd/E13222_01/wls/docs81/capplan/capgen.html

PBTech (2017). *Computer Parts, Laptops, Tablets, Monitors, Mobile Phones & More - PBTech.co.nz*. Retrieved 10 July, 2017, from http://pbtech.co.nz/

Portnoy, M. (2016). *Virtualization essentials*. Retrieved from http://www.proquest.com/products-services/ebooks-main.html

Schwalbe, K. (2014). *Information technology project management*. Retrieved from https://www.cengage.co.in/

Subraya, B. M. (2006). Web-Based Systems and Performance Testing. In B. Subraya (Ed.), Integrated Approach to Web Performance Testing: A Practitioner's Guide (pp. 1-28). Hershey, PA: IGI Global. doi:10.4018/978-1-59140-785-0.ch001

Swanson, E. B., & Dans, E. (2000). SYSTEM LIFE EXPECTANCY AND THE MAINTENANCE EFFORT: EXPLORING THEIR EQUILIBRATION. *MIS Quarterly*, *24*(2), 277-297.

W3computing.com. (2017). Technical Feasibility - Hardware and Software Needs. Available at: http://www.w3computing.com/systemsanalysis/ascertaining-hardware-software-needs/

Why the GNU Affero GPL. (2015) *Free Software Foundation.* Retrieved from https://www.gnu.org/licenses/why-affero-gpl.html

Zhu, J., Mauro, J., & Pramanick, I. (2003, June). Robustness benchmarking for hardware maintenance events. In *Dependable Systems and Networks, 2003. Proceedings. 2003 International Conference on* (pp. 115-122). IEEE.

Acknowledgement

Adrian Cyrus Limpin - *IT support Engineer.*

Shared his knowledge gained during his career and from his current employment. Helped identify the main elements in the “Other elements of an in-house implementation” section. The organization he works for implements the approaches mentioned in the disaster management plan.

Mark Allen Amarante - *Network engineer.*

Assisted with understanding how networks function. His input was significantly important in acquire the correct information about the venue infrastructure and understanding how it impacts project. Also provided input on hardware necessities for expanding the existing wireless networks at the venue.

Akshay Raj Gollahalli *- Team supervisor, current PHD student at AUT.*

Assisted greatly with feedback and guidance for all parts of the project. His assistance with the technical assessment was critical for the development of this report. His experience and understanding helped us in our research and assessing the correct artefacts involved in the project.

Gillian Frankcom-Burgess *– MATHEX Judge.*

Interviewed to ask for MATHEX competition details as well as feedback about the new system. She explained how the MATHEX competition worked as well as the roles of everyone involved in the competition. Her feedback allowed us to gain a more significant understanding of the competition as well as new requirements for the system.

Brian Tomlinson *– General Manager at ASB Stadium*

Interviewed to investigate existing venue infrastructure and setup of venue during MATHEX events. Helped organise a visit to the ASB Stadium. Provided information on existing networks and technological solutions for the system implementation.

Jonathan Hopcroft – *Infrastructure Lead*

Guided and provided knowledge about network infrastructure and ways to approach the project. Helped set us in the right direction for what to research.

Appendix A

This quote was provided by PB Tech on the 23rd May of 2017. Please note that some fields were excluded and part descriptions were kept to their minimum for the purpose of this report. An Excel spreadsheet is available containing the full information.

Description	Qty	Unit Price	Node Price
Database Server			
1028R-WC1RT Barebone	1	$2,466.30	$2,466.30
Intel Xeon E5-2620 v4 2.1GHz Processor, 8Core/16Thread	2	$590.00	$1,180.00
Crucial 16GB DDR4	8	$245.00	$1,960.00
Samsung Enterprise SSD PM863a Series, 960GB	6	$697.65	$4,185.90
Intel SSD DC S3520 Series, 150GB	2	$150.00	$300.00
CacheVault Supercapacitor	1	$371.48	$371.48
Mounting Bracket	1	$59.48	$59.48
Labour	2	$60.00	$120.00
		Node Subto.	**$10,643.16**
Reverse Proxy Server			
1028R-WC1RT Barebone	1	$2,466.30	$2,466.30
Intel Xeon E5-2620 v4 2.1GHz Processor, 8Core/16Thread	2	$590.00	$ 1,180.00
Crucial 16GB DDR4	8	$245.00	$1,960.00
Samsung Enterprise SSD 480GB	6	$375.29	$2,251.74
Intel SSD DC S3520 Series	2	$150.00	$300.00
CacheVault Supercapacitor	1	$371.48	$371.48
Mounting Bracket	1	$ 59.48	$59.48
Labour	2	$ 60.00	$120.00
		Node Subto.	**$8,709.00**
Application Server			
1028R-WC1RT Barebone	1	$2,466.30	$2,466.30
Intel Xeon E5-2620 v4 2.1GHz Processor, 8Core/16Thread	2	$590.00	$1,180.00
Crucial 16GB DDR4	8	$245.00	$1,960.00
Samsung Enterprise SSD 480GB	6	$375.29	$2,251.74
Intel SSD DC S3520 Series	2	$150.00	$300.00
CacheVault Supercapacitor	1	$371.48	$371.48
Mounting Bracket	1	$59.48	$59.48
Labour	2	$60.00	$120.00
		Node Subto.	**$8,709.00**
Total			**$ 28,061.16**

Appendix B

This quote is a modification of Appendix A to reflect the suggestion in the hardware specification section. Please note that some fields were excluded and part descriptions were kept to their minimum for the purpose of this report. An excel spreadsheet is available containing all details.

Description	Qty	Unit Price	Node Price
Server			
5018R-M Barebone, 1U	1	$1,227.00	$1,227.00
Intel Xeon E5-2620 v4 2.1GHz Processor, 8Core/16Thread	1	$590.00	$590.00
Crucial 16GB DDR4	4	$245.00	$980.00
Samsung Enterprise SSD PM863a Series 960GB	2	$697.65	$1,395.30
Intel SSD DC S3520 Series, 150GB	1	$150.00	$150.00
CacheVault Supercapacitor	0	$371.48	$0
Mounting Bracket	0	$59.48	$0
Labour	2	$60.00	$ 120.00
		Node Subto.	**$4,462.30**
Total			**$ 4,462.30**

Appendix C

This appendix provides short definitions for the terms used in the Hardware Specifications section. Links to research are provided if further explanation is needed.

ECC (Error Correction Code)
Protects against data corruption by automatically detecting and correcting memory errors. Commonly used in servers for data security measures.

- https://www.pugetsystems.com/labs/articles/Advantages-of-ECC-Memory-520/
- https://www.servethehome.com/unbuffered-registered-ecc-memory-difference-ecc-udimms-rdimms/

RAID (Redundant Array of Independent Disks)
Approach used to enhance performance and/or data protection. There are several ways that RAID can be implemented.

- https://rog.asus.com/articles/maximus-motherboards/what-is-raid-setup-guide/

PLP (Power Loss Protection)
Feature of solid-state drives (SDD - storage device) that protects data against sudden power loss.

- http://www.samsung.com/semiconductor/minisite/ssd/downloads/document/Samsung_SSD_845DC_05_Power_loss_protection_PLP.pdf

CacheVault Supercapacitor
Helps avoid the possibility of data loss or corruption during a power or server failure. It is an extra security measure for the system. This is redundant due to the RAID approach and PLP.

- https://www.pbtech.co.nz/product/BATSPMCVM02/Supermicro-CacheVault-Supercapacitor-for-Cached-Da

UPS (Uninterruptible Power Supply)
An electrical apparatus that provides emergency power when the input power source or main power fails.

Barebones
In this context, the barebones are the cabinet and motherboard of the server. By definition, a barebones PC is a computer that has minimal components. A typical barebones system includes a case, motherboard, CPU, hard drive, RAM, and power supply.

Cache
Computer memory with very short access time used for storage of frequently or recently used instructions or data.

Caching
Process of storing data into a cache.

MATHEX Competition Flow