Responsive Design and Content Adaptation for E-learning on Mobile Devices

Vivek Bhuttoo, Kamlesh Soman and Roopesh Kevin Sungkur

Department of Software and Information Systems, Faculty of Information, Communication and Digital Technologies, University of Mauritius, Réduit, Mauritius

Abstract— **In this multi-screen world, we spend most of our time shifting through devices from desktops to laptops, tablets, and smart phones, in different modes, sequentially and simultaneously. Orchestration of these learning contents from multiple devices is not an easy task. It is also a fact that there has been an explosive growth of mobile devices and practically every learner nowadays has a mobile device. This represents an immense potential for learning purposes. Mobile learning is undoubtedly not e-learning on mobiles. Expecting all e-learning courses designed for desktops to work equally well on mobiles is against the basic thinking of ubiquitous learning, since each of these devices is perfected for different needs, and possesses unique features. Presently, most of the rapid e-learning development tools in the market do not support responsive design. The aim of this research has been to develop a responsive mobile learning application and to investigate on its ability to provide content adaptation based on certain conditions such as limited bandwidth. A mechanism has been designed whereby the mobile device can identify the strength of the Internet connection available. The system operates on two metrics; round trip time and bandwidth and using these two metrics, contents to be displayed on the mobile device are eventually adapted. Azure Cloud storage has been used to build this platform. The resulting application is cross-platform and can be run on Android, Windows phone and iOS.**

Keywords— Mobile Learning, Tablets, Content Adaptation, Responsive Design, Cloud Storage

I. INTRODUCTION

Mobile devices are the mostly used for the purpose of e-learning obviously because of their portability. However there are so many different designs of these devices each built on different platforms nowadays that it has become difficult to make a unique design which will fit in all of the devices present. Another issue is about the content to be displayed, these need to be optimized both with respect to hardware specifications of the machine and also the needs of the user. The solutions used to address these issues are known as responsive design and content adaptation respectively. E-learning contents and materials developed are used on computers, laptops, tablets and smartphones and all of these have different characteristics not necessarily compatible with providing a consistent learning experience. However constraints of mobile devices such as restrained screen size, limited connectivity, high power consumption rates and limited input modalities are well-known (Harrison et al, 2013). Besides these, very often it is argued that other attributes, such as cognitive load, tend to be overlooked in the usability models that are most prominent despite their likely impact on the success or failure of an application. To remedy this Harrison et al (2013) introduce the PACMAD (People At the Centre of Mobile Application Development) usability model which was designed to address the limitations of existing usability models when applied to mobile devices. Besides, learning can take place in different environments, indoor or outdoor and in situations where there is limited internet connection. In cases of limited Internet connection, it is perhaps preferable to have the learning contents in the form of text, rather than multimedia. Different learners also have different learning styles and have different ways of learning.

II. LITERATURE REVIEW

A. Mobile Devices

The number of mobile devices in use is rapidly increasing and is very effective for people on the move, allowing people to perform more task in a mobile context. As technology evolves, the tendency is to replace ordinary computer devices such as the personal computer by mobile ones. In May 2014, as mentioned in an internet article at Mobiforge, the International Telecommunications Union (ITU) estimated that 7 billion people worldwide (95.5 % of population) have a mobile phone in their possession. Among these users, Emarketer (2014) estimates that by 2016, 2 billion users will have a smartphone in their possession. This figure is expected to go on increasing since Smartphones are becoming more affordable nowadays.

B. Education and M-Learning

Education is the process through which knowledge and experience is acquired which results in a change of behavior, understanding capabilities and skills as discussed by AgriInfo (2015). Furthermore, there are three types of educations through which most of us go through: Formal education, non-formal education and informal education. Fordham (1993), Formal education is about what we learn in school, whereby everything that is being taught follows a plan and is assessed afterwards. Non-formal education in many cases forms part of formal education where the goal is to have the learner have his own experiences (an educational tour organised by an educational institution could be an example). Informal education, on the other hand is everything that we learn from everyday life experiences. According to Habib and Hoque (2010), e-learning has various meanings and varies in different

978-1-5386-3831-6/17/$31.00 ©2017 IEEE

literature. Most learners, especially the younger generation are already familiar with mobile technologies and its capabilities. E-learning on mobile platforms (also known as mobile learning) can promise great flexibility due to the intense amount of features offered by new generation smartphones. Lehner & Nosekabel (2010) mention that mobile-learning has become a major extension of e-learning. M-learning can be defined as "any service or facility that supplies a learner with general electronic information and educational content that aids in the acquisition of knowledge regardless of location and time". Despite the good virtues Mobile Learning brings about, Picek and Grcic (2013) argues that most of its weakness lies in its backbone, i.e. mobile devices itself. Mobiles are small, have limited CPU power, screen size and battery power. This much is enough to put limitations on mobile learning techniques but however, there is much more to the list. The numerous amounts of platforms (android, iOS, windows mobile and blackberry) and device types available on the market makes it very difficult to build one unified solution. Another weakness is that designing and implementation of mobile learning platforms require special skill set which very few possess. A mobile learning platform is meant to be user-friendly and needs to adapt throughout the devices available on the market. Also mobile devices make use of wireless means for communications which puts a question mark on security features.

C. Responsive Design

A great number of learners now rely on their mobile devices and smartphones to access their learning materials. Hence E-learning professionals and content developers find it a must to come up with contents that are easily accessible and fully adaptable. Responsive design is an approach where the objective is to eliminate the need of redundant designs so as to match the specifications of devices from which an application is being viewed. For example, let's say we have two tablets of which one has a full HD screen and the other having a 640 by 480 pixels display. A responsive design will allow display of an application on both devices by dynamically adapting the content according to the device. Responsive design makes use of latest web technologies such as HTML5 and CSS3 to scale up and scale down web designs. In traditional web designing, web designs used to be fixed and object sizes were defined in pixels. Such designs maintained their scale no matter of the screen size in use. In responsive designs, percentages are used to define these and hence the interface remains the same no matter on which device the content is being viewed from.

Figure 1: Responsive Design

However, after matching facts with articles published by Cremin (2011) on mobiforge.com and Graham (2015) on css-tricks.com, Responsive design is not the only technique used to adapt content over devices. Other techniques such as Adaptive design, progressive enhancement and server-side adaptation are also used to achieve device-independent designs. Graham states that the difference between responsive and adaptive is that responsive will take content and adapt to any screen size by resizing the content. In adaptive designs however, specific layout for specific screen sizes are built in order approximately match different screen sizes. Adaptive designs are easier to implement but however they lack responsiveness whereas responsive web designs are hard to implements since the usage of percentages in web programming are not obvious and requires a lot of skills to be dealt with.

Using progressive designs according to Cremin (2011), makes use of JavaScript to build layout into the device in which the web interface is being loaded. Progressive designs however can cause performance issues since some computing power along with networking capabilities are required in order to achieve such a type of design. Server-side designs are server dependent and make use of the server's computing power to eventually transform content to adapt to the mobile's hardware specifications. An example of such adaptation could be an application for online video streaming which converts and streams video to devices according to their speed and screen sizes. Despite being very complex to build, the best design is a hybrid design combining responsive html design along with client and server side design adaptation techniques and order to perform content adaptation. This technique and the progressive design technique are the only ones which allow the developer to cater for context-awareness.

D. Content Adaptation

Because content adaptation is one of the technologies that support adaptive versions of content for heterogeneous devices, there is an increasing demand for content adaptation for a Web-based learning environment (Huang et al, 2012). According to Cremin (2011), modern applications make use of content adaptation to fit the same application on different screens. There are a lot of techniques nowadays which allows this to be done among which responsive design is one.

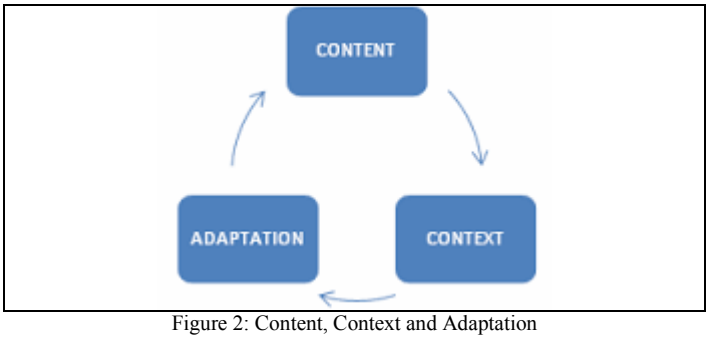

Figure 2: Content, Context and Adaptation

To make the concept simple, it can be said that Content Adaptation is the process of transforming content to adapt to device capabilities.

Content Adaptation can also be viewed from another perspective where it can be said that content adaptation can be done for a specific learner where the learning contents undergoes user adaptation. In addition to the discrepancies of learning devices, learners may have different abilities, preferences, motivations, and knowledge. Some Web-based systems are devoted to develop the techniques of content adaptation for the problem of device heterogeneities (Laakko & Hiltunen, 2005).

E. Cloud Services

Cloud can be defined as a service which consists of servers where client can get access to them via some specific software. Normally found in data centers, these servers are spread across the world and connected with very high internet speed. It follows a Pay-Per-Use principle and consists of services such as: Infrastructure as a service (IAAS), Software as a service (SAAS) and Platform as a service (PAAS) (Gajbhiye, 2014). Associated with Cloud Computing, Mobile-Cloud Computing (MCC) is an emerging subject in the new world of technology.

As better smartphones with higher specification and more optimized operating system are being developed, it can be deducted that on a consumer level, mobile device is at trend rather than regular big screen desktop. MCC can be classified as the major trend for the future generation. For the forthcoming years, improvement in wireless technology will contribute to MCC allowing ease of access from the user perspective (Hazarika, 2014).

Azure is a recent product of Microsoft Corporation; it is a cloud service that allows to perform various activities such as analytics, computing, database, mobile, networking, storage and web. Azure web services works very well with Microsoft Visual Studio 2015. With features such as "Mobile services", it makes the development of mobile applications easier and these can be hosted on the cloud. Azure web services shows to be a very efficient tool when it comes to mobile development (Microsoft azure, 2015).

Figure 3: Windows Azure Mobile Services (Umer 2013)

F. Xamarin

Xamarin has been acquired by Microsoft in 2016 and represents an interesting solution for the development of native Android, iOS and Windows Apps with native user interfaces and can share codes across platforms of Windows and macOS. Mobile Applications developed using Xamarin not only look the way the user expects it to be but also behave that way too. Traditional Xamarin made use of C# base code and native UI design in order to build apps. This means that for each target platform the UI had to be coded separately. In the newer Xamarin.Forms, we make use of pages defined in XML known as XAML pages in order to design the UI which can be interpreted on all of the platforms, hence the ease of having cross-platform development.

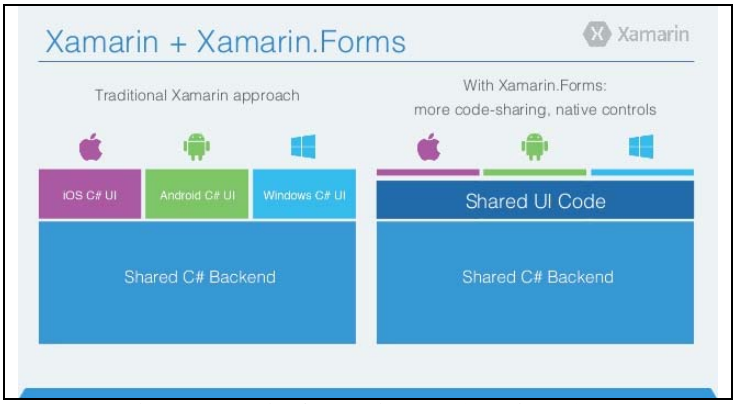

Figure 4: Xamarin v/s Xamarin.Forms (Horesh 2016)

III. PROPOSED SOLUTION

A. Architectural Design

The system will be working on 3-tier architecture. The client, server logic and server data will be on separate layers. The following diagrams fully illustrate how the whole of the

system has been designed. Both viewed from an internal and an external perspective.

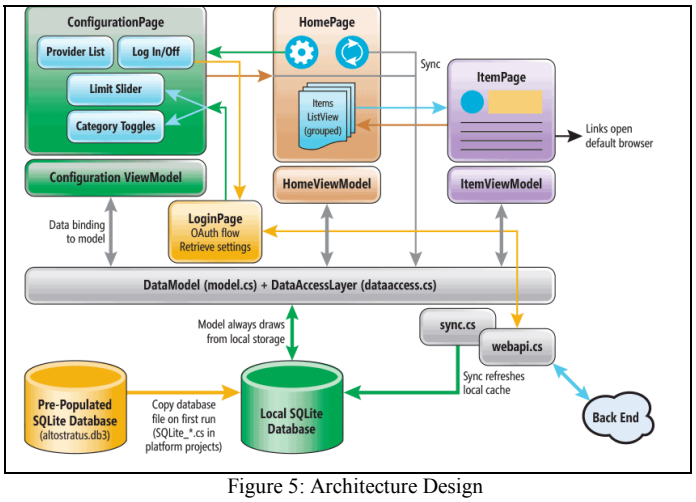

Figure 5: Architecture Design

The external view of the system developed and how it interacts with the different components is shown in Figure 3 below

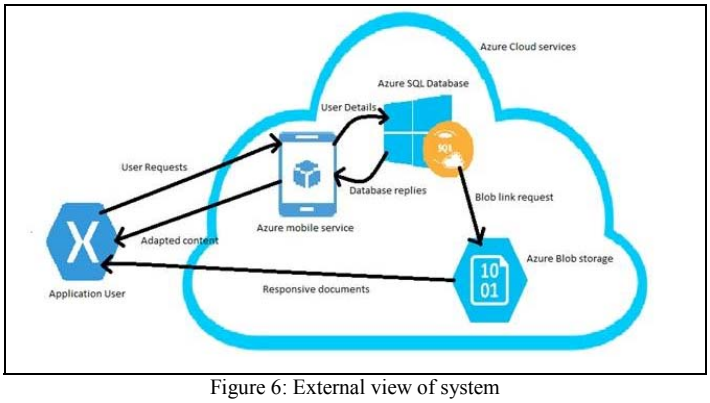

Figure 6: External view of system

B. Component Design

The most important components of the architecture are the Xamarin application, azure storage and the mobile service. The Xamarin application is the application itself which are used to allow the user to interact with the system with the help of a User Interface. The azure storage is split into two storage facilities, the blob storage and the SQL database. Both of these databases are different services. The blob storage allows the storage of any kind of file of any kind of format. These files can then be accessed using a public link. The SQL database provides Relational Database service where structured relational data can be stored and retrieved using the mobile service. The mobile service provides backend facilities such as backend processing or data modeling which saves the CPU power and storage capabilities of the user.

C. Algorithm used to detect Bandwidth

The system we designed operates on two metrics: round trip time and bandwidth. Every time the user is about to open a page, the system gathers those metrics and compares them to a hardcoded minimum value. If the RTT is too high or bandwidth is too low, the user is prompted a message asking for permission to omit images. The algorithm also uses a small file of 100KB. It downloads this file from a server and then the time taken is used to get the network speed.

D. Development Environment

Xamarin with visual studio 2015 were used to develop the cross platform application for content adaptation. Xamarin with visual studio 2015 uses Xamarin.forms which uses C# as programming language for building up native cross platform apps. Xamarin provides student licence together with visual studio license from a DreamSpark account. Azure SQL database has been used to store user information and other relevant information. Documents in HTML format and its equivalent in PDF format have been stored in Azure cloud services in a BLOB storage. An Azure mobile service has been used to allow interaction from a device to the cloud documents. When connecting mobile services to azure database, a URL and access key is used to ensure secure access. From the developer's side the NuGet Package for Azure mobile services has to be installed. NuGet packages are simply libraries that are automatically added to the project through available from an online collection. The connection to be database can then be set up by instantiating an instance of the client. Since azure supports entity data, no database codes are to be written. The mobile service automatically converts class instances into JSON which is sent to be further handled by the server.

E. Responsive Design using MVVM Framework

In Xamarin.forms, a framework known as MVVM (Model View ViewModel) is used to create applications. MVVM is similar to MVC (Model View Controller) in java. It separates the Model(Entity Classes), the View(the User Interface) and the ViewModel (the logic behind the user interface which makes it usable). A XAML is an XML-format document which defines elements to be rendered when a page is created in C#. When a XAML page is created in Visual Studio, an associate class file is created in order to control views or data in use by the page.

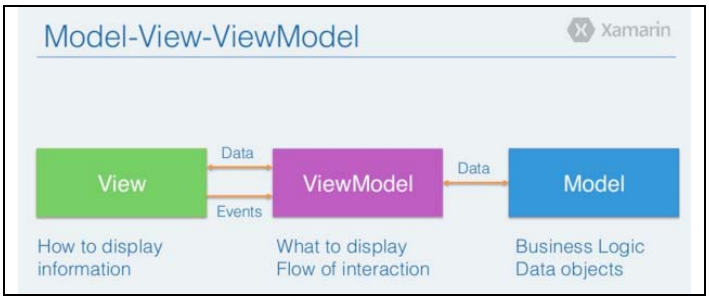

Figure 7: MVVM

IV. RESULTS AND INTERPRETATION

A. Responsive Design

The application developed using Xamarin.forms provided excellent responsive design for learning materials developed. Contents developed were able to be responsive enough to be used of computers, tablets and smartphones of different screen sizes. A number of tests were done to confirm the responsive nature of the design obtained using the above development environment and the results were very much positive. Many E-learning content developers should now see to it that when they are developing E-learning contents, adaptation and responsive design, especially for mobile devices, do not come as an after-thought but should be something that has been carefully planned and considered.

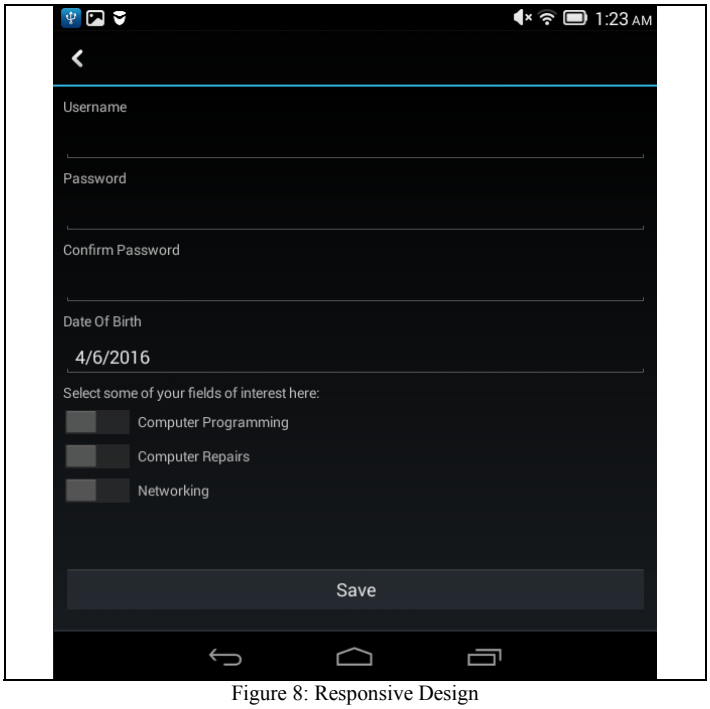

Figure 8: Responsive Design

The portrait orientation on a seven Inch (7”) screen shows that the different items present on the page response to changes

B. Experiments with different Bandwidth

This experiment consists of testing for HIGH and LOW bandwidth and loads the content of the page accordingly. When deploying the application, the system automatically detects the bandwidth of the network as explained in the section below. The screenshot below shows how the system responded to high and good connectivity on the network. The system automatically gathered metrics and decided that the internet connection is good and can load the pages correctly.

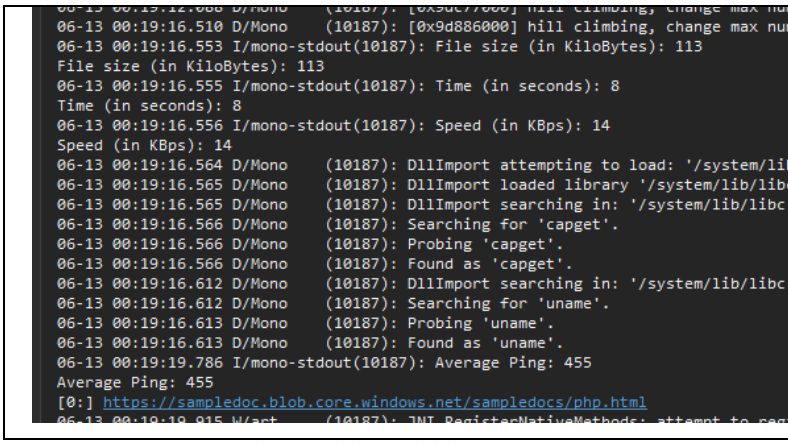

Figure 9: High Bandwidth

This is done using two conditions the ping value and the network speed. It can be noticed in the screenshot that the ping value is 455ms which indicates a fair connection between the host and the client with minimal packet loss. The speed is indicated as 14kbps which the system identifies as a fair speed to display images. The user will hence, be able to experience highest resolution images that will be displayed. The following screenshot shows how the page was displayed with high resolution pictures.

In this scenario, the algorithm chose to display the images without the need to prompt the user about low connectivity since the metrics revealed good connection speed. The engine determined that the connection was fast enough for images to load quickly enough.

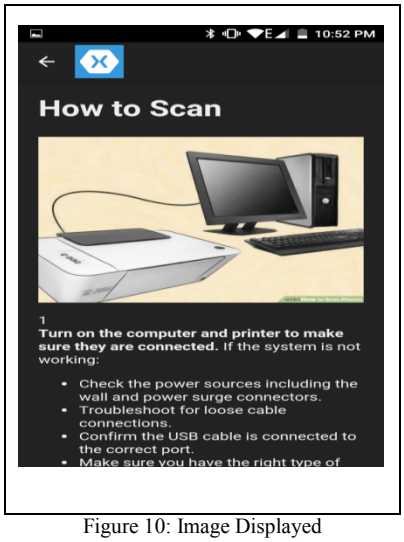

Figure 10: Image Displayed

The figures below show how the system responded to a low connectivity situation. Since the metrics it gathered did not match the minimum requirement, the user was prompt a confirmation message on the front-end to disable display of images.

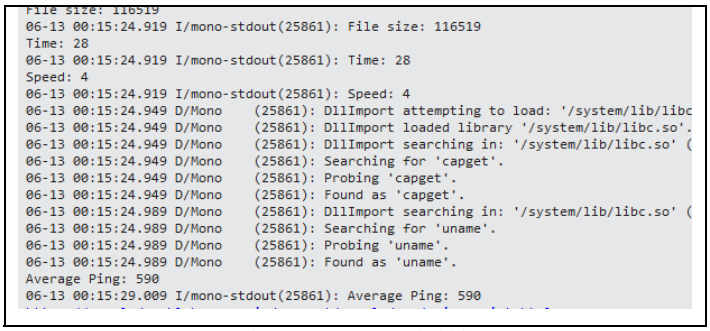

Figure 11: Low Bandwidth

The speed of the connection is 4 Kbps and the average ping is 590ms. These values indicate low bandwidth with high packet loss. In this scenario the system will prompt the user if he wants to omit images because of low speed connection. The screen on the left is prompted to the user if the system detects poor connection. The user is still given the choice whether to load images of not. Further improvement of the system can be achieved by grading the connection speed and then 'handpicking' the quality of images to be sent or not to be sent at all.

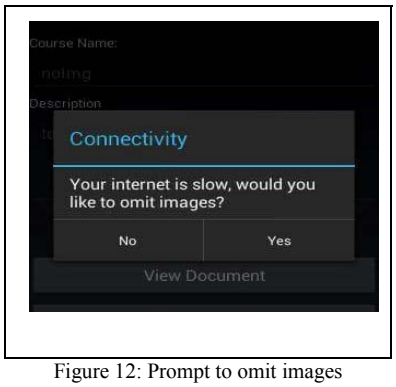

Figure 12: Prompt to omit images

V. DISCUSSIONS AND CONCLUSION

The aim of this research was to investigate how responsive design and content adaptation can be incorporated on the preparation and design of E-learning materials. This is an issue of utmost importance especially for mobile devices where one of the well-known limitations of learning to happen over mobile devices is its restrained screen size. It has to be borne in mind that the learning process can take place at anytime, anywhere, on different devices and in different situations. Coupled with this is the fact that each learner has different learning profiles and styles and that designing a similar learning content to be used by all learners is to follow the concept of one-size-fits-all which is not really the ideal situation. This research has also enabled the design of a mechanism whereby the Internet Connection Speed of the learner is identified and in response to that the contents, especially multimedia contents are adapted to make the learning process smoother and adapted to the situation. The current system works by choosing between omitting images and displaying them. Another way to adapt content based on bandwidth availability could have been to grade the network performance rather than directly measuring the bandwidth. This can be done by sending two ping requests of different sizes and then measuring the difference. The system will then use this metric to grade the network and decide which quality of images to use to display documents to the user.

REFERENCES

[1] Mobiforge (2014). Global mobile statistics Part A: Mobile subscribers; handset market share; mobile operators. Available at: https://mobiforge.com/research-analysis/global-mobile-statistics-2014-part-a-mobile-subscribers-handset-market-share-mobile-operators#subscribers. [Accessed 27 December 16].

[2] Habib, A. and Hoque, A. S. (2010) 'Proceedings of 13th International conference on computer and information technology', Bangladesh: ICCIT. pp. 300–304.

[3] Lehner, F. and Nosekabel, H. (2002) 'The role of mobile devices in e-learning first experiences with a wireless e-learning environment', Proceedings. IEEE International Workshop on Wireless and Mobile Technologies in Education, (4), pp. 148–150. doi: 10.1109/wmte.2002.1039229.

[4] Picek, R. and Grcic, M. (2013) 'Evaluation of the Potential Use of m-learning in Higher Education', Cavtat, Croatia: ITI. pp. 63, 64.

[5] Cremin, R. (2011). Mobile web content adaptation techniques. Available at:https://mobiforge.com/design-development/mobile-web-content-adaptation-techniques. [Accessed 24 January 17].

[6] Graham.G. (2015). The Difference Between Responsive and Adaptive Design. Available at:https://css-tricks.com/the-difference-between-responsive-and-adaptive-design/. [Accessed 24 January 17].

[7] Gajbhiye, A. & Shrivastva, K. M. P. (2014). Cloud computing: Need, enabling technology, architecture, advantages and challenges. Confluence The Next Generation Information Technology Summit (Confluence), 5th IEEE International Conference.

[8] Hazarika, P. (2014). Mobile-Cloud Computing. The Mobile-Cloud Computing Roadblocks.

[9] Microsoft Azure[online], available from: https://www.azure.microsoft.com/ [Accessed on 28 December 2016]

[10] EMarketer. (2014). 2 Billion Consumers Worldwide to Get Smart (phones) by 2016. Available at:http://www.emarketer.com/Article/2-Billion-Consumers-Worldwide-Smartphones-by-2016/1011694. [Accessed 27 December 16].

[11] Harrison, R., Flood, D. and Duce, D. (2013) Usability of mobile applications: literature review and rationale for a new usability model. Journal of Interaction , 1:1, Springer Berlin Heidelberg.

[12] Horesh, A.B (2016) 'Build Cross-Platform Android and iOS UIs with Xamarin Forms. https://www.sitepoint.com/build-cross-platform-android-ios-uis-xamarin-forms/ [Accessed on 28 December 2016]

[13] Umer , M. (2013) 'Windows Azure Mobile Services – State of the Art Cloud Backend for All of Your Applications', https://blogs.msdn.microsoft.com/pakistan/2013/03/19/windows-azure-mobile-services-state-of-the-art-cloud-backend-for-all-of-your-applications/ [Accessed on 28 December 2016]

[14] Laakko, T., & Hiltunen, T. (2005). Adapting Web content to mobile user agents. IEEE Internet Computing, 9(2), 46-53.

[15] Huang, H. , Wang, T and Hsieh, F. (2012). 'Constructing an Adaptive Mobile Learning System for the Support of Personalized Learning and Device Adaptation'. International Educational Technology Conference, IETC, Procedia - Social and Behavioral Sciences 64 (2012) 332 – 341.

[16] AgriInfo. (2015). Meaning and Types of Education. Available at: http://agriinfo.in/?page=topic&superid=7&topicid=524. [Accessed 25 December 16].

[17] Fordham, P. E. (1993) 'Informal, non-formal and formal education programmes' in YMCA George Williams College ICE301 Lifelong Learning Unit 2, London: YMCA George Williams College.