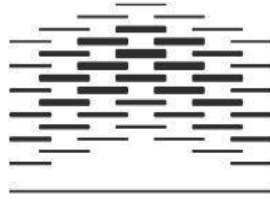TALLINNA ÜLIKOOL

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IMPACT OF MOBILE TECHNOLOGY ON DIGITAL LIBRARIES

ABSTRACT

With the rapid advancement in technology in last two decades, mainly because of the advent of internet, the world no longer works the same. The advent of wireless networks and more recently mobile devices such as smart phones, tablets etc following the internet, contributed a lot to make mobile technology come into existence. The technology has gone on miles since then and there has been no looking back.

Mobile devices, which were initially devised with an intention to replace telephones using wireless technology, have now become a very important part of daily communication not only for telephone service users but also for the internet users. Recent studies conducted at different places reveal that the volume of usage of internet using mobile devices is increasing at a very rapid pace. The two main reasons behind success of mobile technology is the benefits such as mobility and ubiquity served by mobile devices. The existing technology is obviously expected to improve rather more in future. These are the reasons why mobile technology is seen as future of communication by many.

Mobile devices need an underlying support from Operating System and also need hardware and software support to communicate properly. The devices communicate across different platforms using a communication channel so they also need a defined set of protocols and network support in order to communicate and as mentioned earlier they need internet connection to communicate.

Impact of Mobile Technology on Digital Libraries

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1 INTRODUCTION

Computer technology has created a revolution with new advances, new ideas and new users for machines that once were considered useful for handful of tasks and industries. Thus with the scope and ubiquity of computer technology libraries and librarians need to remember that effective and relevant library services are driven by user needs. These technological advances have altered the more traditional forms of information provided by libraries. With the advent of technology libraries are no longer the way we imagine with books on row upon row in a building with a person sitting in front. The world of library and librarian has changed by digital technology. Digital libraries are collection of documents, artifacts, video, images etc. stored together on a computer in digital form. Technology has changed the fundamental forms of information and the way to find access and use information.

The digital libraries provide individuals to advance their knowledge and skills and access digital collections also serving as a community center for communication and collaboration. This also offers challenges how library professionals will organize, store and distributed information with several forms a book can take such as networked book where authors and readers collaborate online to create it. Similarly the technologies such as social networking are the changing the way users produce access and process information. The advanced algorithms and networked books significantly alter the way how users find, absorb and read information.

As technology evolved, mobile computing has gained increased popularity with widespread use and is on track to replace personal computers (desktop and laptops) as the primary means to access online information and communication. Accessing digital libraries over mobile devices has the high potential of reaching a broader community of users which will also give rise to issues related to making digital libraries accessible over mobile devices. Mobile technology is altering the way we communicate, teach, learn, entertain ourselves and make decision. Mobile devices today can run complex software allowing user for advanced interactivity and with new hardware and technologies such as Bluetooth, Wi-Fi, global positioning system, mobile websites mobile devices can send and receive information nearly anywhere and anytime. Libraries can serve better by adapting the growing mobile technology offering mobile access to their websites

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and public access catalogs and by providing mobile access to e-books, journals, video, audio books, and multimedia contents.

1.1   Digital Libraries

A digital library is a special library with a collection of digital objects that can include text, visual material, audio material, video material, stored as electronic media formats along with means for organizing, storing, and retrieving the files and media contained in the library collection. Digital libraries provide a search interface which allows resources to be found. The backbone of any digital library is computer software, hardware and the reliance of high speed networks. Any digital library rely on components such as local networks with connections to the internet, databases with user friendly interfaces for searching and administrative purposes which can index documents for fast access. A digital collection of documents are done by acquiring original digital works such as articles, books, conference proceedings, pictures etc. done by original authors, converting paper originals to digital format, dealing with right management issues such as copyright.

The digital library today uses different documents formats for storing and representing the content. A file format is a software algorithm for encoding the data and information about the data. Further they can be proprietary, developed by commercial companies or open file formats that are available for anyone. ASCII (American Standard Code for Information Interchange) and UNICODE are most widely used character set encoding. Similarly, MSWord are proprietary formatted-text formats. Page Description format describe shapes and the layout of a document. The most applied of these formats are Portable Document Format (PDF). Graphics Interchange Format (GIF) and Joint Photographic Experts Groups (JPEG) are different formats that are used to store information of pixels in still images. For Audio and moving images the formats are such as AIFF, MP3, AVI.

Digital libraries contain metadata, documents, audio, images, video in different formats, created with different software which makes information retrieval complex task. Further usability is affected by the knowledge of search topic or domain and the knowledge of system used by the

user. For digital libraries, user experience and good search strategy is vital to get good search result.

Digital libraries can be maintained by individuals, organizations, or affiliated with established physical library buildings or institutions, or with academic institutions where content may be stored locally, or accessed remotely via computer networks.

1.2 Mobile Technology

With the rapid advancement in technology in last two decades, mainly because of the advent of internet, the world no longer seems to work the same. The advent of wireless networks and more recently mobile devices such as smart cell phones, tablets etc. following the internet, contributed a lot to make mobile technology come into existence. These handheld devices saw a lot of advancement in the last decade. The wireless networking and internet also witnessed a lot of reforms and discoveries which only made them better and more suitable to use for various mobile operations. As a result of which mobile technology has gone on miles since these discoveries and inventions, and there has been no looking back since then.

Mobile devices, which were initially devised with an intention to replace telephones using wireless technology, have now become a very important part of daily communication not only for telephone service users but also for the internet users. These mobile devices are now popularly used, especially among youths, for the purpose of accessing contents on internet. Recent studies conducted at different places reveal that the volume of usage of internet using mobile devices is increasing at a very rapid pace. In fact, research suggests that, there were about 250 million wireless internet enabled devices in use in the United States in the year 2009[1].Ownership rates for mobile technology based devices out runs those for non-mobile technology based devices; in fact, there are eight times more iPhone/iPod Touch users 2 years after their launch than there were AOL users 2 years after its launch [2]. Statistics suggest that there were about 4.6 billion mobile cellular subscriptions worldwide at the end of 2009, which represents two-thirds of the world population [3].Mobile industry analysts suggest that, according

to the statistics, worldwide mobile data traffic has doubled every year through 2013, increasing 66 times between 2008 and 2013[4].

The reason behind success of mobile technology is the benefits such as mobility and ubiquity served by mobile devices. Mobile devices today have the capability to play rich multimedia content, allow for advanced user interactivity, run increasingly complex software and interact with cloud services. New hardware and technologies such as Bluetooth, accelerometers, and multi-touch screens, as well as text messaging, smart phone software applications, mobile websites, global positioning systems (GPS), Wi-Fi, and media creation and capture tools, are all part of the mobile environment. Mobile technology is seeing an increasingly wide range of uses in our daily lives. The existing technology is obviously expected to improve rather more in future. The use of mobile technology in any field is highly beneficial and is the reasons why it is seen as future of communication by many.

Mobile devices need an underlying support from Operating System to efficiently manage and manipulate the hardware resources available to the device and also need software support to carry on operations smoothly without any glitches. Two of such handheld mobile devices may run on different platforms with a few differences in architectural and organizational design. These devices also need to communicate with each other if they are part of same organizational system or often they need to communicate across devices of other organization as well. Such communicating devices may have different underlying platform. For this very purpose we need network support so as to communicate across devices not only of similar platform but also of different platforms. The communication is carried out using a communication channel so they also need a defined set of protocols in order to carry out communication in a standardized form. And as mentioned earlier they also need a working internet connection to carry out communication. Extent of success of mobile technology is mostly dependent on mobile devices and network support. Hence we can come to a conclusion that the design of mobile devices and networking has a large impact on implementation of mobile technology.

1.2.1   Defining Characteristics

The reason that mobile technology is considered as future of technology is because of the properties it posseses such as mobility/portability, ubiquity, resource sharing and utilization etc. In this section, we discuss about various such properties of mobile library that makes it different from traditional libraries. Let us have a look at few of its following properties:

1.2.1.1   Availability/Ubiquity

Almost all the traditional libraries around the world have a specified operation time during which they are available to users and are also location specific. Unlike traditional libraries these mobile libraries can be accessed from anywhere and at anytime. This is the sole motivation that would draw users towards it. This important factor is of very major importance in todays world because most of the works today are being carried out in distributed fashion and it would be highly useful to be able to access resources from remote places as well. It also guarantees convenience to users in accessing the contents wherever and whenever they want. Being able to access contents from remote places will eventually open doors of possibilities of educating people of far off remote places, where it was considered to be very tedious task earlier. Thus easy and convenient global access to resources is the main defining characteristic of mobile library.

1.2.1.2   Resource Utilization and Sharing

In traditional libraries once a resource is issued other users cannot access the very same resource until the user returns it or the library has another copy of it. With this approach there is always a chance of resource exhaustion and a user may not get the resource he seeks for. With mobile library, however, we would not face any such problem as it would rather give users access to digital copies of resources while being available to distribute digital copies of it to other users who seek for it as well. This will guarantee a user that he will definiately be able to access any resource available in the library and also need not go through hectic formalities of issuing and returning a book as in traditional libraries. This sharing of resources is of high importance specially in case of academic resources because a traditional library has to keep many copies of

same resource for being able to provide resource to all of the students while a mobile library will simply enable access to its digital copy for all the students. Mobile libraries, however, can always set limit to the number of users that can access same resource at a time. This decision is solely left on them.

1.2.1.3   Cost Efficient

Today the world has become more and more economy concious and any organisation wants to maximize its profit while minimizing its expenditure. Mobile library would prove to be cost efficient to both administators and users. A traditional library requires a huge physical structure (Building) to keep all of the resources in one place. Then it needs a lot of library and human resource as well. Routine examination and maintainance of building also adds to expenses. As the traditional libraries provide physical copies of resources there is always a risk of damage to its resources which demands for its replacement. While a mobile library needs a small building to protect all its hardwares from external risks and once it is installed, the administators only need human resource for its maintainance. The very low expenditure on library resources however is the main advantage that will motivate administators to make a transit to mobile library. The users however have less prospect of economic benifit but will definiately be benifited to some extent.

1.2.1.4   Popularity of Mobile Technology among youths

It is another very important aspect to look out for. Majority of the user population belongs to youth and mobile technology is something that they are very familiar with and is also very popular amongst them. Mobile devices have now become an integral part of life for most of the youths and they are also very good at using it and do posess ability to discover and cope up with changes as and when required. This helps to sort out issue of socio-technological implementation to a great extent. It is also something that is expected to grow more and will eventually become a inseperable part of living. So, it can be fruitful to switch to the use of mobile technology as far as libraries are concerned. Since it is very much in trend so traditional libraries might feel boring to

some users and if library administators do not realise this fact as soon as possible users may loose interest in library.

1.2.1.5   Mobility/Portability issues for users

Library users need not carry the books along with them wherever they go. They just need to have access to the library system and then can access the contents without needing to be physically near the library system. It not only provides physical mobility but also various operational mobilities.

1.2.1.6   Miscellaneous

It would also prove to be environment friendly as it would reduce the paper usage by a very huge margin all over the world as most of the works would then be digitized. It can also ease the task of building unnecessary library buildings which would specially turn out to be benefitial in rural areas because all we need then would be internet connectivity.

Digital Technology has provided faster access to information and it is also challenging the libraries to rethink and remodel their services by adopting the technological changes. Today mobile phones are becoming an integral part of everyday life and are changing the way one connects and interacts with the world. In this changing scenario, Mobile Technology will be of great help to libraries towards strengthening their relationship and providing enhanced user oriented services to existing users. The technology shift from traditional desktop computing to mobile computing affects many areas including digital libraries. This raises the question how libraries will evolve in face of this mobile technology revolution. Thus our goal is to identify what the technology evolution to mobile technology is i.e. the way its implementation is different than the traditional approach , its defining characteristics and how libraries have adapted mobile technology i.e. how successful are libraries at using this technology.

2   LITERATURE REVIEW

Mobile computing is a term coined after use of mobile devices for computing purposes using mobile technology. The introduction of mobile computing has transformed the way of interaction with information. Within a few years of its introduction smart-phones have gained immense popularity resulting in skyrocketing in its ownership and thus the use of e-readers has been steadily on the rise. With these advanced mobile tools we can access information instantaneously, across boundaries of subject, discipline and industry, almost from anywhere and at anytime.

2.1   Background

Libraries can better serve their users by embracing the growing capabilities of mobile technology. They can promote and expand their existing services by offering mobile access to their websites and online public access catalogs; by supplying on-the-go mobile reference services; and by providing mobile access to e-books, journals, video, audio books, and multimedia content. Infact, libraries today are in the process to upgrade themselves to fulfill increased demand for electronic collections. As per the study conducted by American Library Association study in 2010, 66 percent of public libraries offered e-books to their users which was recorded 55 percent the previous year. And according to the very same study an estimated 63 percent of libraries offer online video content and about 83 percent offer online audio content [5]. Now efforts are underway to allow mobile access to these collections. Inspite of the economic challenges for libraries to take on new technological initiatives, the librarians across the nations are seeking for creative solutions to provide mobile library services. In this particular section, we will have a brief insight into various studies and research conducted in the field of mobile technology and its feasibility of its application in libraries.

Rosa Reis and Paula Escudeiro from Instituto Superior de Engenharia do Porto (ISEP), Portugal and Nuno Escudeiro from Faculdade Economia Universidade do Porto, Portugal came togather to conduct a case study named "Educational Resources for Mobile Wireless Devices"[6]

where they came to a conclusion that integration of mobile technology in educational process requires analysis of the methods of teaching, learning strategies and content design. The study also mentions that mobile technology has become an important part of the young generation so it would be proved beneficial for the teaching learning process to link educational resources with the increasingly popular mobile technology.

Another research that has been conducted regarding application of mobile technology is named "Analysis of Factors Influencing the Mobile Technology Acceptance for Library Information Services : Conceptual Model"[7] by Sununthar Vongjaturapat, Nopporn Chotikakamthorn and Singha Chaveesuk of King Mongkut's Institute of Technology Landkrabang Bangkok, Thailand. The findings of the research indicate that the increasing popularity of mobile technology because of its benefits, such as being able to access information from virtually anywhere and at anytime, students expect to access their institutes' service from their handheld devices. To cope with this trend, they have proposed a theoretical model for academic institutes and service providers. The contribution of the model is a design guideline for the mobile technology function that is consistent with a service function in the library context.

A. M. Amaral from Centre for Innovation, Technology and Policy Research from Instituto Superior Técnico, Technical University of Lisbon discusses about methodological and socio-technological challenges in the implementation of mobile technology in firms in his paper named "Learning and Adapting to Mobile Technologies: An Intra-organizational Assessment"[8]. This paper supports that introduction of mobile-ICT (Information Communication Technology) will inevitably interact with a wide spectrum of individual and organizational elements, which will have significant implications for the adoption, understanding, and swift adaptation to the technology. The paper also mentions about the possible challenges its implementation could face due to lack of knowledge among the related users.

A survey was conducted in early 2011 at Utah State University (USU) with approximately 25,767 undergraduates and graduates to determine the degree of handheld device usage in the student population of which 3,074 students responded representing 11.9 percent of the total population, the purposes for which students use such devices, and students' interests in

mobile access to the library. Further librarians were surveyed to learn about libraries' current and future plans to launch mobile services [11]. The response showed 54 percent of undergraduates and 50 percent of graduate students use mobile technology for academic purposes. The majority of students used electronic books, the library catalog, and electronic journals/articles a few times each semester. Only 34.4 percent of students never use electronic books, 19.6 percent never use the library catalog, and 17.6 percent never use electronic journals/articles. The comparisons between disciplines were made and no significant differences were found in electronic resource use between fields in the sciences and those in humanities. Further, responses show that 39.3 percent of our students use a smart phone with Internet access on a daily basis. Another 31.5 percent of students use other handheld devices like an iPod touch on a daily basis. Students were asked if they use their mobile device or phone for academic purposes, 54 percent of respondents indicated that they use their mobile devices for academic purposes. The results were further analyzed by discipline and just a few variances were found. Among students 59 percent of engineering students used their devices for school work and 63 percent students from School of Business said that they use their mobile device for academic purposes. Further the students were asked, "If library resources were easily accessible on your mobile devices, and if you had such a device, how likely would you be to use any of the following for assignments or research?" Among the survey respondents, 70.2 percent are likely or very likely to use resources on a smart phone; 46.9 percent are likely or very likely to use resources on an iPad; 45.9 percent are likely or very likely to use resources on an e-book reader; 63.2 percent are likely or very likely to use resources on other devices. A separate survey with librarians among 289 librarians and library staffs to find out how long they had been providing mobile access, what services and resources they believe libraries should provide via mobile devices. Of 178 responses 71 percent indicated that everything or a variety of library resources should be made available.

Similarly through research conducted in Nigeria revealed high possession of internet capable device which are used for information search through various means [12]. Researchers recommend academic libraries should consider the developmental process of adopting mobile

technology for providing library services since library users have preference to use mobile technology for information search.

Ayoob Nazi, Sakineh Ghamsepour and Leyla Asgari (2014), conducted a descriptive survey by collecting required data from 150 randomly selected samples using a questionnaire developed by researcher [13]. The results showed that 68 percent of respondents supported the use of mobile phone in the library. Mobile of 89 percent respondents had support multimedia and internet browsing facilities and 54% said they would upgrade their mobile phones in future. Further the library services suggested were SMS based services, Website based services, Client/Server based services for all popular mobile platforms and operating systems, mobile hardware based services, and Voice call based services.

Open University of Malaysia (OUM), the pioneer in open and distance learning in Malaysia initiated and introduced OUM Mobile Library to support its learners in their acquiring knowledge and learning process [14]. In August 2011 OUM Mobile Library was introduced and initiated to support its learners in their acquiring knowledge and learning process. Since there are different devices with different capabilities, OUM Mobile Library makes use of Wireless Uniform Resource File (WURFL) API, Drupal Mobile Tools Module and conditional CSS to cater each device with different capabilities. More powerful device will have extended display such as better button and dialog boxes and the less powerful devices will have lighter theme to reduce CPU load.

2.2 Implementation Issues

The implemetation of mobile technology in libraries is a multi dimensional task, each posing various challenges in its implementation. In this section we discuss about various such dimensions and issues it poses on its implementation.

The term socio-technological refers to interaction between technology and people at workplaces. Whenever there is technology it involves a skilled and well trained actors to utilize it to yeild a better efficiency in its use. Here the actors can be any of mobile library administators or users. Technology is something that can rapidly change in a blink of an eye, so it demands the

actors that act upon it to be open and ready to learn new things and respond quickly to technological changes and upgradations as and when they happen, which is indeed an lifelong phenomena that is expected to occur when we talk about embedding technology to workstations. Mobile Technology is still considered to be in its early stages as of now so we can expect a lot of changes to occur in the existing technology and to cope up with the changes a lot of expertise and ability to respond to changes and upgradations will be required.

The use of mobile technology for library will introduce an entirely different environment for interaction between user and library services than the traditional libraries. In the traditional libraries all the contents and resources of library are on full display within the physical library building where, users can interact with librarians, browse the stack of books and journals, and use computers for an immersive information search and retrieval experience. This level of interactivity and connectedness has not yet been achieved in the library experience through mobile technology due to various challenges posed by the practical considerations — such as connectivity, hardware, and mobile interface design.

The ability for users to interact with library services virtually or through mobile devices is however advancing inspite of all the challenges lying in its way, offering new opportunities for information search and retrieval. The library experience for users is expected to improve rather more in the future with the advancement in technology. Ongoing researches in the field of real-time embedded systems and virtualization techniques are expected to yield some fruitful discoveries and inventions that can be embedded with the mobile library.

The implementation of mobile technology for libraries demands the actors to be dynamic as it involves an entirely new library experience and rapid adaptation to the latest technology which may be completely different than the existing one. This might in turn demand a few changes in working ways of library administation & management and may also force its users to learn new things before they can make use of it, which may be inconvenient to a few. Therefore, all these parameters discussed above should be taken into serious consideration while setting up a mobile library.

The implementation of mobile library demands an extensive use of technology at different levels. Any compromises in the implementation of such technological aspects at any level might result in inefficient working of the library and will definiately affect library environment. The technological implementation of mobile technology includes various aspects such as networking issues, hardware and software issues, system organisation and architecture issues, etc. It would be better to discuss them seperately. A brief insight of the implementation of each of them is discussed below.

The first and foremost issue regarding technological implementation would be networking. The entire concept of mobile technology is dependent on networks and the extent of success is largely dependent on effeciency of networks and its implementation. The successful implementation of mobile library needs to ensure reliable network connectivity that can operate 24x7x365 without any glitches and errors. Apart from this, the network should also be secured from external threats and protected from internal errors for that would guarantee an uninterrupted service. Any external threat to the library can result in the leakage of potential information to the wrong hands can be fatal. The result of any mishandling of library information or the any alteration in the original information would be a fatal setback to the library system. It can even lead to complete reconstruction of the mobile library. A user's private data, if any, will also be in all sorts of danger which will largely influence the user experience too. Internal protection of the system holds equal importance for the successful implementation. At times there can be some issue regarding extent of access of one library resource by another library resource. Provisions regarding this should also be thoroughly determined to protect the system from any internal damages.

When we talk about operating system in this context we are talking about operating system at both the ends i.e, user and the library, as both are involved in the communicating process of the mobile library systems. An operating system by definition, is a program that manages system hardware and software resources and provides common services for computer programs. It is also responsible to ensure interaction with other devices.

Operating system at library end has a larger role to play in this context as the usability of the library system is entirely dependent on it. It handles all the resource access requests made by the users and grants, rejects or delays the access to the resources based on authenticity of the request, availability of the resource and other access parameters defined by the library administration. As mentioned earlier it will also manage all the hardware components at the library end. Its role is to ensure that all the authentic users get uniform treatment by the library system. Operating system can also have mechanisms for protection and security of the entire mobile library system. While Operating system at user end has no effect on usability of the mobile library system by other users than himself/herself. The only thing user needs is that the operating system should allow user to connect to internet so that he/she can access the library contents.

Every system is composed of numerous hardwares and softwares, which are an integral part of any technology. Hardwares are the physical components of a system and softwares are programs designed to specifically perform one or more tasks. Hardware implementation includes establishment of central system for the library, so only the administators are concerned with the issue. After setting up the system, more important part of its implementation is the routine upgradation of hardware components as the technology that is based on the hardware keeps changing demanding changes in hardware as well. Hardware replacement should not affect the working of other hardware components and if it does affect, then it may require some changes in other hardwares as well.

As technology changes very fast, any system requires to upgrade its softwares or programs very qucikly and swiftly to cope up with latest technology out there in trend. As realised from the trend so far evolution of hardware is a slow process as compared to evolution software. Therefore the library system administators should always be prepared to embrace the new technology. Sometimes software changes may also lead demand in hardware changes but most of the times software changes are based around the existing hardware, so that we need not make hardware changes each time we want to upgrade the software.

In computer engineering, a system architecture describes the functionality, organisation and implementation of the system. It includes major aspects system instrumentation such as Instruction Set Architecture (ISA) design, microarchitecture design, logic design and implementation. The way in which system information flows, the instructions get executed and processes work is termed as organisation often known as microarchitecture. Same architecture can be used in different organisation and same organisation can also be used over different architectures. Both these factors are left upto library administators as it is a design choice. The administators can choose a system architecture and organisation well suited to their needs, capacity and reports based on other feasibility studies.

While talking about giving online access to outsiders, there always involves a risk of possible privacy breach for both, the users and the library system. For a user, a library system can keep track of details of contents that the user accesses, which sometimes a user may not be acceptable to the user. Such monitoring over content acess or access time may disinterest the user leading to negative impact on user experience. The user can sometimes be redirected to third party resources which may not be reliable and may also disinterest the user. As the communication process takes place in both directions, the library system is also exposed to equal threats and risks. A malicious user may try to infect the system, so the system should also be fully aware of the malicious activities carried out by the user. As any user can access the online resources, there is always a concern regarding copyright, publication and distribution rights. Also, the contents of mobile library must not pose any kind of threat to the society and people. If there is any information of such potential, it should be handled carefully. For example, in most of investigations of terrorist activities, it was found that they use internet as a means to prepare and upgrade to new technology arms and gadgets. All these issues must be considered while designing the library system to make the system work flawlessly without any legal or privacy intervention. One of the method that can be adopted to resolve this issue can be use of QR codes as a means to verify registered user.

3   METHODOLOGY AND THEORY

Mankind is truly advancing into the "Age of Mobilism", so online libraries can niether ignore the mobile-based "Connected Age" which is evolving nor treat it as some sort of secondary priority and remain focused entirely on the desktop-based internet age. The challenge we now face is to precisely define as in what to include in the terms "mobile library application", "the mobile context" or "the mobile library". As we have to take the resources, the services and the information all to be used easily on mobile devices into consideration, defining the exact parameters may take very wide range of scope to be considered. Having said this, then the question that arises is the selection of devices to fit into the scope, which could again have a wide range of choices from small screen hand held device with a full web browser also including the tablet device within it to the laptops as they also serve the purpose of mobility.

Now, considering all these boundary parameters, for the purposes of this report we are considering the full range of native apps, web apps, responsive website, mobile website. Also, this thesis include the full range of resources, services and information about library service. However it does not consider lower end feature phones as our baseline is solely the Smartphone with a full web browser. This thesis really focus only upon iOS and Android models. Despite of being aware of other platforms as well, the motivation to drop other platforms in this thesis derives from the fact that sample statistics indicate they only account for a minority percentage of the library mobile usage in various institutions. Tablets such as the iPad and android tablets are included in the discussions of this thesis. Although the inclusion of tablets seem to complicate things here because of their slightly larger size and ability to perfectly run most of the full desktop websites than most of the smartphones – but screen size is not the only aspect to be considered as far as discussions in this thesis are concerned. It is included because of ease in its mobility and also touch-driven nature which is also a key feature of smartphones.

However, the discussions in this thesis are limited only to smartphones and tablets, not including laptops or net books . Although, laptops or net books do satisfy the condition of mobility but are excluded because of their extreme processing capabilities, ability to perfectly render complete desktop environment and also because it is not a very convenient option to carry

around as compared to tablets and smartphones. Recent advancement in both smartphones and laptos have however made it more and more difficult to distinguish between them. Specifically the development of hybrid net book/tablet devices and arrival of Windows 8 and touch screen for desktop and laptop have thinned the line of distinction between laptops and smartphones further. Inspite of all these driving factors to include laptops in our discussion we technically dismiss them as they are handheld and they belong to the set of devices that employ the desktop WIMP (window, icon, menu, pointing device) computing metaphor, rather than the handheld NUI (natural user interface) metaphor.

This paper is not concerned about the library policies such as membership policies, access timing policies, access volume policies, wether or not to allow full content access to users who are not members of the library, etc. Before moving to further discussions in upcoming section let us have a look at timeline and trends for both mobile devices and libraries.

1970s	In the late 1970's, early efforts were made to device portable phones and computers
1990s	- Introduction of World Wide Web in early 90s. - Mid 90s witnessed the emergence of PDAs such as Palm coming to market. - Smartphones emerged in the late 1990s
2000	First camera phone developed.
2001-2002	- Palm software was included in mobile phones, Microsoft launched its Windows mobile software and the Blackberry from RIM emerged – features phones are cutting edge devices. Reading email and taking low resolution photos possible, browsing the web more an idea than a reality - Apple's iPod was released in early versions

2007 June 19	Apple release iPhone/iPod and the App store, a step leap in the multifunctional mobile device, the first touch screens Smartphone. Not just texting and phone calls – here you had full web viewing, fully rendered web pages to move around in plus listening to media, creating photo and video all on the mobile device not the desktop – this was the game change when it came to viewing the web on mobile, a totally different experience to the early WAP access, which was mainly text based with limited colors and used over slow connections.
2009	The first Android device is made available
2010	• Apple release the iPad • The app store and other stores really take off
2012	Smartphone ownership reaches tipping point

Table: Mobile Devices Timeline and Trends

Following are some of the worth noting surrounding factors that made smartphone experience better that are not mentioned in the table above:

- Costs of smartphones coming down.
- Transition from 2G to 3G and 4G networks offering very high transfer speed.
- Wi-Fi becoming widespread and often free in locations, allowing a shift from phone calls only to widespread use of mobile media as well without incurring large costs.
- Mobile devices got eqquiped with advanced features like GPS and the also capability to install apps as per requirements from app store.
- Meanwhile advancement in processing capabilities, memory and storage capability, introduction of multi-core processing and multithreading etc opened opportunities for its application in new fields.

So far we have very limited knowledge about the mobile library timeline but advancements in this field has been going on for around a decade now. So now let us have a look at few sample dates followed by some discussion of the relatively low and slow rate of development in this area.

2004	Individual libraries such as Ball State University and North Caroline State University created mobile library websites for ease of use on feature phones, pioneers in this area
2009	District of Columbia Public Library. Built app to browse and search library materials, translating catalogue search to mobile setting
2010	Libraries start to use location sensitive features. In early 2010 North Carolina State University released Wolfwalk, a historical walking tour with archival photos used
2013	A sizeable number of libraries still have no mobile-friendly catalogue or other presence – at the same time significant numbers of native and web apps have been developed by libraries

Table: Library Timeline

Now that we have been introduced to most of the background knowledge, we are ready to carry the thesis further on. Before we move any further we must know that the thesis presents its content based on study conducted using documentary analysis and observations drawn from it. However few of the contents were innovatively discovered during the course of study.

4   ANALYSIS

4.1   Mobile Technology Implementation

Mobile Technology is a technology that allows transmission of data, voice and video via a computer or any other wireless enabled device without having to be connected to a fixed physical link. The main components of mobile technology are mobile software, mobile hardware and mobile network.

A cellular network or mobile network is a communications network where the last link is wireless. The network is distributed over land areas called cells, each served by at least one fixed-location transceiver, known as a cell site or base station. This base station provides the cell with the network coverage which can be used for transmission of voice, data and others. In a cellular network, each cell uses a different set of frequencies from neighboring cells, to avoid interference and provide guaranteed bandwidth within each cell. When joined together these cells provide radio coverage over a wide geographic area. This enables a large number of portable transceivers (e.g., mobile phones, pagers, etc.) to communicate with each other and with fixed transceivers and telephones anywhere in the network, via base stations, even if some of the transceivers are moving through more than one cell during transmission.

Second generation 2G cellular telecom networks were commercially launched on the GSM (Global System for Mobile Communications) standard in 1991. 2G technologies enabled the various mobile phone networks to provide the services such as text messages, picture messages and MMS (multimedia messages). All text messages sent over 2G are digitally encrypted, allowing for the transfer of data in such a way that only the intended receiver can receive and read it. 3G telecommunication networks support services that provide an information transfer rate of at least 200 kbit/s. 3G telecommunication networks support services that provide an information transfer rate of at least 200 Kb/s. Later 3G releases often denoted 3.5G and 3.75G, also provide mobile broadband access of several Mb/s to smart phones and mobile modems in laptop computers.

A mobile hardware is mobile devices or device components such as a smart phones, notebook, Personal Digital Assistant (PDA) WAN modem, LAN adapter etc. Samsung, Apple, Nokia, Xiaomi, Lenovo are few vendors for manufacturing mobile device. Mobile Software is operating system or OS-type software that resides in mobile device. It may be Andriod, Blackberry, and iOS. Similarly it may be a mobile

application user interface with application logic in handheld device or a application software or database server software. Mobile software deals with the characteristics and requirement of mobile applications.

4.1.1 Mobile Devices

The number of searches using mobile devices is steadily increasing, and trend shows no signs of slowing down. Users enjoy the ease of searching via a wide range of smartphones, different types of tablets, or even a laptop. A mobile or handheld device is an electronic device that enables some kind of computing, and which is small enough to be easily carried around. Mobile devices are used for a whole range of digital services that we rely on every day. Use of desktop computer is still relevant but the use of mobile devices for digital services has skyrocketed in past several years. In US, between December 2010 and December 2014 the usage of smartphone has increased by 394 percent and tablet usage is up by 1721 percent which account for 60 percent of digital media time spent [15].

Smartphones are used widely among the mobile devices. Smart phone is a mobile phone with an advanced mobile operating system which combines features of a personal computer operating system with other features useful for mobile or handheld use. The essential features in modern day mobile systems are a touchscreen, cellular, Bluetooth, Wi-Fi, GPS mobile navigation, camera, video camera, speech recognition, voice recorder, music player, near field communication and infrared blaster. The worldwide smartphone market grew 13 percent year over year on 2015 Q2[16]. Samsung retained the topmost position with 21.5 percent market share. Apple was in second position with 13.9 percent of market share. Huawei, Xiaomi and Lenovo followed with 8.7, 5.6 and 4.7 percent of market share.

Mobile devices with mobile communications capabilities (e.g. smartphones) contain two mobile operating systems – the main user-facing software platform is supplemented by a second low-level proprietary real-time operating system which operates the radio and other hardware. Many types of operating systems are available for smartphones. However, android dominated the market with 82.8% of market share [17]. Android developed by Google is an operating system based on Linux kernel. Apple's iOS was at second position with 13.9 percent of market share. Windows and Blackberry are among the few other operating systems that are used.

4.1.2 Platform for Developing Mobile Libraries

Options for library development for mobile users are diverse. Initially it seemed there were 2 main options, websites and apps, for developing mobile applications. However it seems there are more options.

Recently Responsive Web Design has developed a great deal. Similarly in-browser apps or web apps are another area that has taken center stage. Thus we have mobile websites, native apps, web apps and responsive web design as different options for developing library application.

Responsive websites are designed to work on any platform as it is a custom CSS stylesheet that makes the website look great on any device. It allows you to have a single website that automatically fits the screen size of the device on which it is being viewed. This is achieved by adapting the content, design, navigation and method of interaction to deliver the same comfort and usability to the mobile user as to the desktop user. A totally responsively designed website is certainly the strategic approach to follow as and when finance and technical resources allow, the entire website displaying useably on any sized mobile device as well as desktops and laptops.

A mobile website is designed specifically for mobile devices considering all the limitations and opportunities of the platform. While developing a mobile website the small screen size, interaction methods (touch) and limited connection speed (2G/3G) are considered. Content must be easily accessible, fast-loading and readable. As there are different mobile devices with different screen sizes and interaction types, it is impossible to create a website per device type even a mobile website has to be a little responsive to fit every screen.
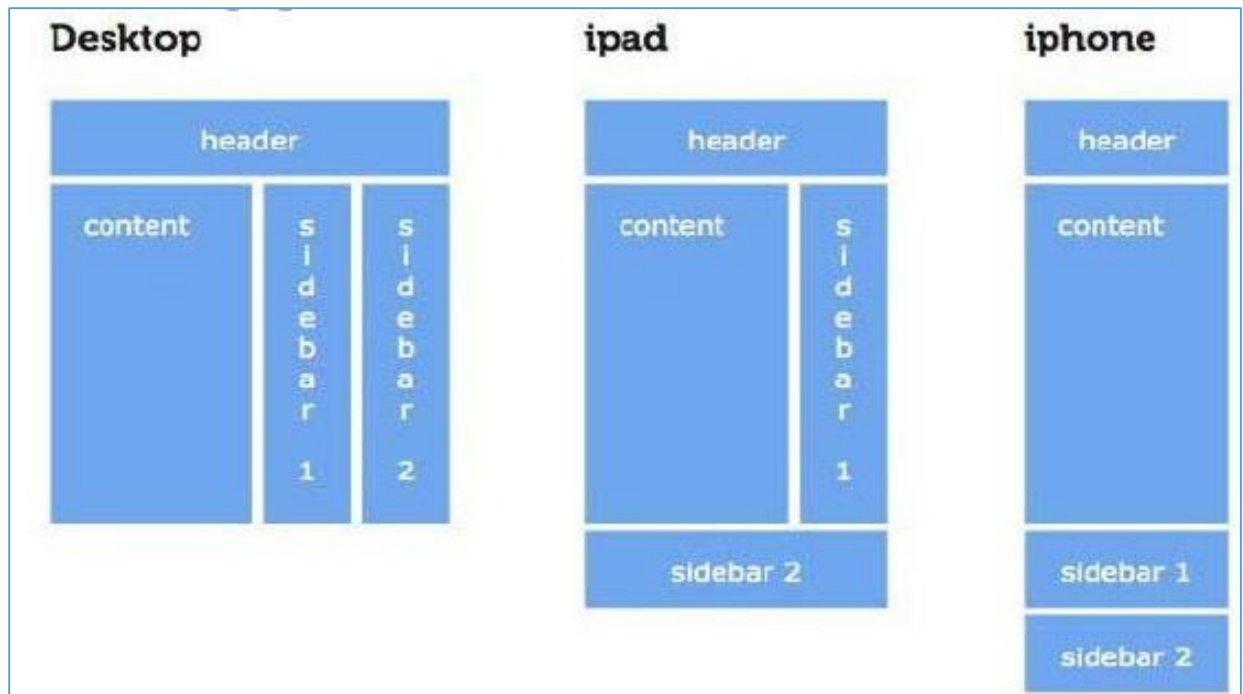
Figure 1 Responsive Web Design

A native app is software specifically developed for mobile devices that run physically on the mobile device and are coded specifically for the operating system of that device. They are usually designed for a very specific and narrow purpose like a game, for banking purpose etc. Users have to download the app mostly from a specific OS store, like Google Play or the Apple Store and install it on the mobile device.

A web application shares characteristics with both a native application and a responsive website. Like responsive website a web application is built using HTML, CSS and Javascript. However, where a responsive site is content orientated, a web application is task focused in much the same way as a native app. Web apps look and feel very much like native apps – they even store data in browser's cache.

Responsive Website vs. Mobile Website

In case of responsive website one has a single website to maintain thus making maintenance easier. However in case of mobile website there will be two websites thus changes will have to be made on both. Similarly, users get a similar experience regardless of device being used if web design responsive. Responsive web designs are easy for SEO (Search Engine Optimization) as it makes easier for Google to index a single site. Further developing one site is cheaper than two which makes it cost effective. Mobile

websites will give better user experience as it is optimized specifically for mobile devices. Similarly it will load fast and easy on mobile platforms.

Web App vs. Native App

Every mobile platform uses a different native programming language. While iOS uses Objective-C, Android uses Java, Windows Mobile uses C++ and so on. Web apps, on the other hand, use languages such as JavaScript, HTML 5, CSS3 or other Web application frameworks as per the developer's preferences. A native app is totally compatible with the device's hardware and native features, such as accelerometer, camera and so on. Web apps, on the other hand, can access only a limited amount of a device's native features. Native apps are more expensive to develop. However, they are faster and more efficient, as they work in mobile device they are developed for. Also, they are assured of quality, as users can access them only via app stores online. Some native and Web apps look and work much the same way, with very little difference between them. The choice between these two types of apps has to be made by whether to develop a user-centric app or an application-centric app.

4.1.3   Other Development Tools

There are wide varieties of platform and browser combinations in the mobile web environment. Screen sizes vary widely, too, from cell phones with tiny screens in the 400-450 pixel range to pocket PCs with screens that are 1000 pixels wide. To make things a little easier during the design process, mobile device emulators can be installed on PC while working on applications. There are several options available. Recent versions of Dreamweaver (CS3 or later) offer a suite of mobile device emulators built into the package. Similarly the official Android SDK Emulator includes a mobile device emulator which mimics all of the hardware and software features of a typical mobile device (without the calls).

While libraries can make their own mobile sites, there are also different services that translate your website into a mobile friendly interface. Kurogo is a comprehensive mobile application platform unlike other platforms, it was designed from the ground up for mobile websites and mobile apps – from the back-end data connectors and business logic to the presentation templates and native iOS and Android libraries. The Kurogo has a lightweight PHP mobile middleware platform (the Kurogo Server) that aggregates and organizes raw, decentralized data sources from many enterprise systems and delivers them through an mobile web experience and native companion applications. This combination of connectors, business logic, presentation templates, and REST APIs – all created specifically for mobile – which is Mobile Optimized Middleware.
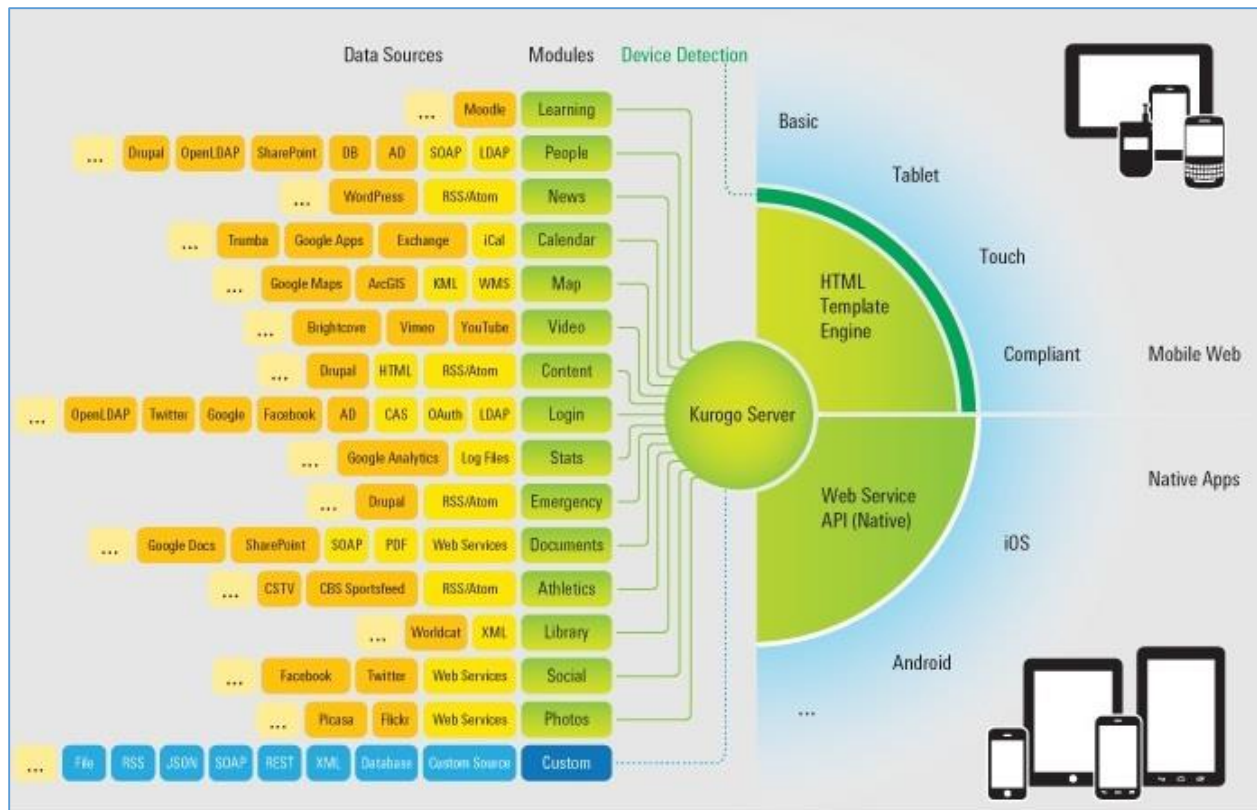
Figure 2 The Kurogo Platform

Mobile web browsers vary widely in speed, display size, and rendering capabilities, but users should have access to the same data regardless of the device they carry. When a browser views a Kurogo-powered website, Kurogo detects the browser's identity and generates pages tailored to the device. While presenting the same data, the pages may look drastically different. Basic devices, such as small screen feature phones, receive minimal, primarily text-driven pages that are small in file size, parsimonious with images, and simple in markup. Touch devices, such as large screen feature phones and older smartphones with touch panels, receive graphical pages that are simple in markup. Compliant devices, including iPhones, Android phones, and many other Webkit-based phones, receive pages formatted for small screens but include more advanced JavaScript/HTML5 and graphic capabilities. Tablet devices, including iPads, Android 3.x ("Honeycomb") tablets, and the BlackBerry PlayBook, receive pages formatted for medium-sized screens, with all the capabilities of compliant devices but showing more content at once. Adapting new content to all the above device categories is made simple -- often requiring zero to just a few lines of code -- due to Kurogo's robust templating system. Based on the smarty templating engine,

each device category has a standard set of inheritable templates for common user interface elements (like lists, tabs, search bars, etc.). Templates may inherit entire pages, or be pieced together to form complete pages, and configured to display data inputs.

Similarly there is need for applications which can run on devices irrespective of the platform being used in the device. Since with the increased usage of mobile devices there is need to develop and deploy more applications which show the importance of the cross platform development tools. PhoneGap, Appcelerator, Adobe AIR, Sencha, Qt are the most popular cross platform development tools. PhoneGap (also known as "Apache Cordova") use HTML, JavaScript and CSS to develop mobile application which run in a "WebView" inside a native application container on the target platform. It is, conceptually, a web application packaged within a native application container where JavaScript has access to device-level APIs that normal web applications would not. Appcelerator's Titanium provides a unified (across devices) JavaScript API, coupled with native-platform-specific features. Developers write JavaScript and utilize a UI abstraction (the Alloy MVC framework) that results in the use of native UI components, greatly aiding UI performance compared to other hybrid options. Adobe AIR is "a cross-operating-system that lets developers combine HTML, JavaScript, Adobe Flash® and Flex technologies, and ActionScript® to deploy rich Internet applications (RIAs) on a broad range of devices including desktop computers, net books, tablets, smartphones, and TVs." Sencha Touch is an HTML5 mobile application framework for building web applications that look and feel like native applications. Qt ("Cute") is a cross-platform development tool that targets a number of embedded, desktop and mobile platforms. Developers write using "QML", touted as a "CSS & JavaScript like language", and apps are backed with an extensive set of C++ libraries, and utilize graphics/UI components written in C++.

There are fairly simple options for creating a simple website including a catalogue with Boopsie or a cloud based tool such as Springshare, Google Mobile Site Builder. A considerable number of libraries are developing mobile website using Library Anywhere (www.libanywhere.com). Library Anywhere also provides an app thereby offering solutions for mobile website and app.

4.1.4   Mobile Services for Libraries

Mobile Libraries are libraries that deliver information and learning materials on mobile devices such as cell phones, PDAs, palm top computers and smart phones to allow access by anyone from anywhere and at any time. Users now can use any service provided by the library even while in commuting as opposed to the conventional libraries whereby learners are confined to physical structure or building. This results

in learners having control of when they want to learn and use library's resources. Thus the mobile services can be as simple as sending a text message alerts about reservations of available books or as complex as accessing a eBooks and journal articles through their library subscriptions on any mobile devices. The libraries can provide following mobile services:

- News and Events
- Mobile Online Publics Access Catalog
- Mobile Library Instruction
- Mobile Library Databases
- Short Message Service Notifications
- SMS reference
- A webcam to check congestion on library

4.1.4.1   Online Public Access Catalogue (OPAC)

An OPAC (Online Public Access Catalog) is an online bibliography of a library collection that is available to the public. It is the online database of materials held by a library or group of libraries where users can search library catalog to locate books and other materials available at library.

4.1.4.2   Quick Response (QR) Codes

QR-Code is one of the factors in attracting users to use m-libraries. This printed two-dimensional bar code is readable by the cameras on most of mobile devices including smart phones. These mobile devices, then, will translate and display the information in the QR-Code. This information is normally a URL that the mobile devices then use to pull up a library's web page or portal. In short, in m-libraries environment and application, QR-Code acts as an authentication entry before one can enter the library portal via mobile devices. Users do not have to type-in their username and password anymore every time they want to visit the library portal via their mobile devices.

Figure 3 Example of QR-Code

Besides as authentication entry, QR-Code also is being used in libraries on library catalogue. QR-Codes are attached to library catalogue records, thereby allowing students to capture bibliographic and location information on their mobiles. QR-Codes are also can be applied during literacy lessons, where links to other media such as YouTube videos placed on handouts.

4.2   Mobile Libraries Implementation

Libraries need to evolve with the change in technology. As the world is moving to the age of mobilism libraries can no longer ignore the mobile connectivity and remain focused on desktop applications. The libraries need to cater the need of users who tend to spent more time on mobile devices. Thus many universities around the world are adopting mobile services for libraries.

Many libraries have developed mobile websites for small screen devices. Dublin Institute of Technology (DIT) has developed a mobile website at http://dit.ie/mobile/. Along with other information library can be accessed using this mobile website. Library services offered using this mobile site are ask, library catalogue search, E-resources (Journals, Books etc.), news, opening hours and more. Similarly St. Angela's College, Ireland made use of mobile website builder Dudamobile to develop mobile website. As of now the old website is not in use however a new mobile website can be found at http://www.stangelas.nuigalway.ie/mobile_files/. Trinity College Dublin had a university mobile website available along with their native apps. The earlier version however has been replaced by using a web app approach.
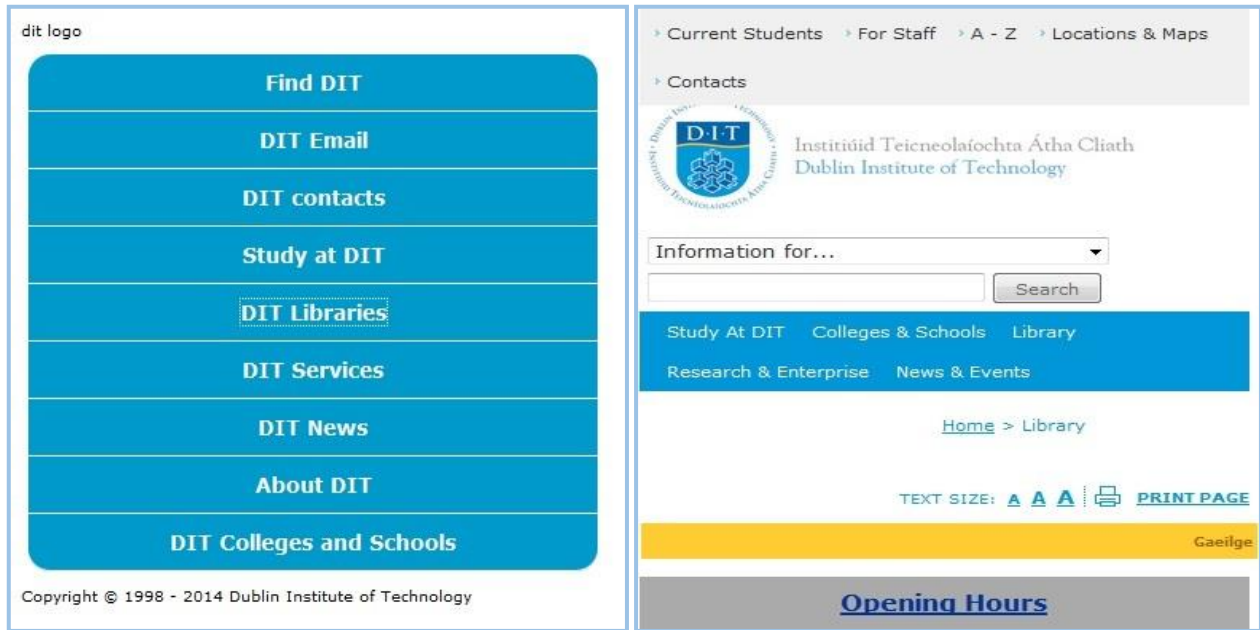
Figure 4 DIT Mobile Website

Figure 5 NCSU Library Mobile Application

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North Carolina State University (NCSU) was one of the early libraries to provide mobile service. A suite of mobile library services was based on MIT Mobile Web Source and launched on November 2009. The services offered were Locations and Hours, Computer Availability, Catalog Search, Ask Us, Webcams, News & Events. The preliminary usage analysis showed that webcam was leading the usage followed by computer availability check and catalog search. However, as of now the University has adopted responsive website with increased services which can be found at http://www.lib.ncsu.edu/.
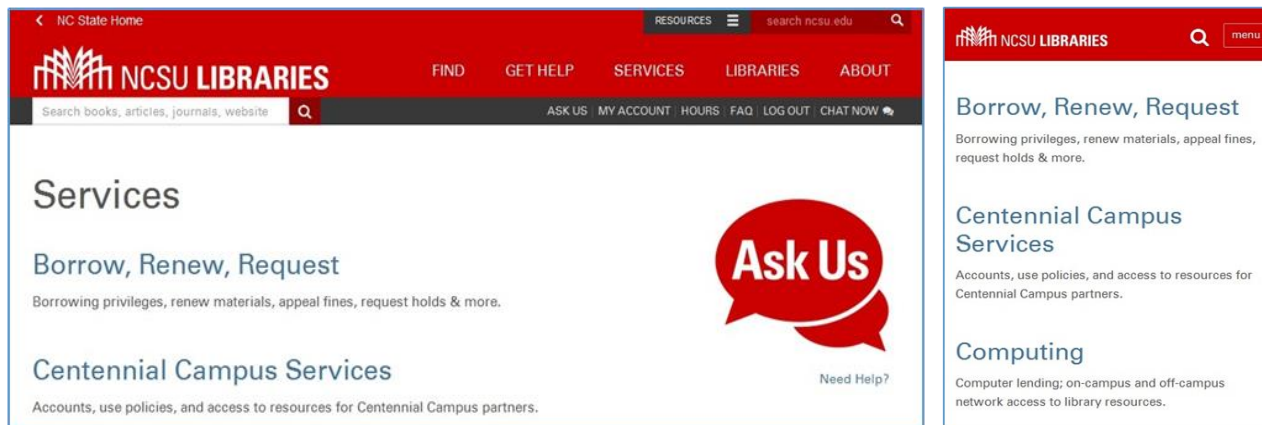

Figure 6 NCSU LIbrary Responsive Website

http://www.libraries.psu.edu/psul/home.html. The mobile library offers most of the services such as catalogue search, databases, journals, opening hours etc.

Figure 7 PSU Library Responsive Website
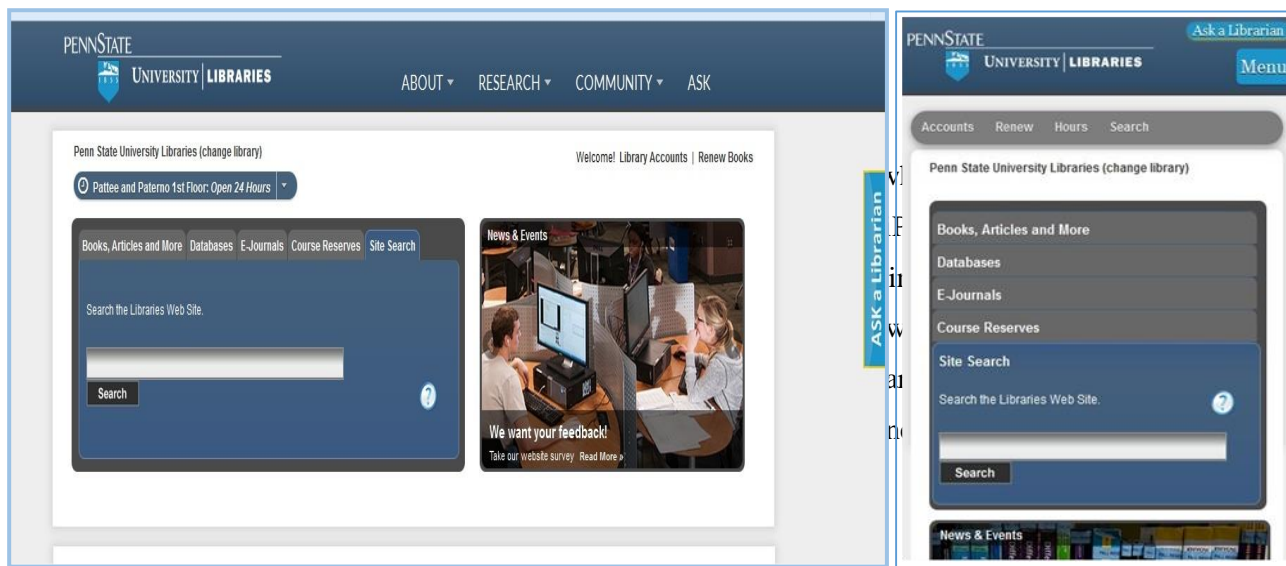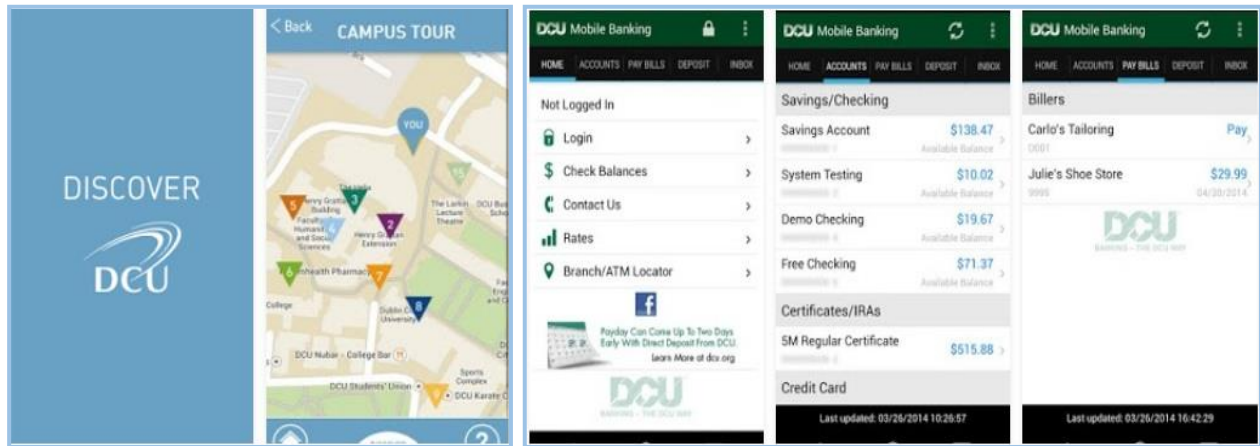
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Figure 8 DCU Mobile Apps for Android Systems

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The National University of Ireland (NUI Maynooth) has an app ("The Maynooth App") for iPad, iPhone and Android. It contains a little library content including summary of opening hours and a link to the separate Library app "NUIM Library". The Maynooth App can be found at http://app.nuim.ie/.

Figure 9 The Maynooth App

Sheffield Hallam was the first university in the UK to go live Blackboard mobile app solution. University College of Dublin followed on the same route and the app is available for iPhone (https://itunes.apple.com/ie/app/university-college-dublin/id459396981?mt=8) and android.
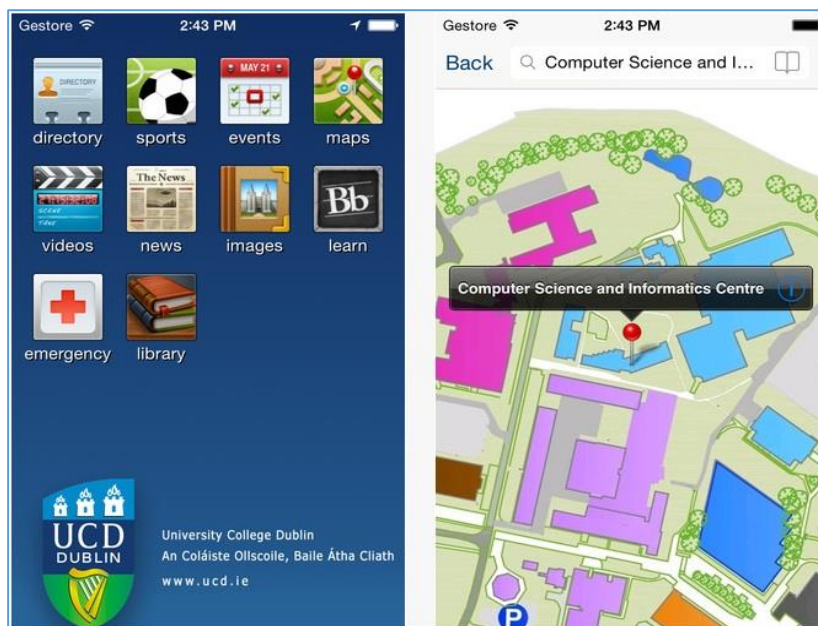
Figure 10 UCD Mobile App

The UCD university app contains a library link which links to the library mobile catalogue. There is information about library locations and opening hours. Library YouTube channel is also included in video section. Further core user requirements of search, reserve and renew are also included.

Similarly the library anywhere provides both mobile website and app to offer library services for its members. The following are the mobile libraries using Library Anywhere service.

Name	URL
Nanyong Technological University, Singapore	http://www.libanywhere.com/la/index.php?dofollow=ult_2252915298-3586604927
University of Canberra, Australia	http://www.libanywhere.com/la/index.php?dofollow=ult_3062674322-2280324533
North Vancouver District Public Library, Canada	http://www.libanywhere.com/la/index.php?dofollow=ult_2117924565-2455519211
Malmo University Library, Sweden	http://www.libanywhere.com/la/index.php?dofollow=ult_1250241749-508088276
Universitat Pompeu Fabra, Spain	http://www.libanywhere.com/la/index.php?dofollow=ult_3677079429-4100258907

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There are many universities across the globe offering mobile library. As there are many frameworks, methods and technologies, each use the technology which best suits their requirement. Similarly services offered by the also varies as per the user requirements. The following is the list of some of the digital libraries supporting mobile devices:

- Aalborg Libraries, Denmark
- American University Library, USA
- Ball State University, USA
- Biblioteca Tec de Monterrey, Campus Monterrey, Mexico
- BI Norwegian Business School, Oslo, Norway
- Open University Library, UK
- University of Pretoria, South Africa
- University of British Columbia, Canada
- University of Navarra, Spain
- ETH Zurich, Switzerland

Some universities that support mobile OPACS only are Black Hills State University, National University of Singapore Libraries and Stavanger Public Library. Libraries with mobile application are Liburutegiak, Public Libraries of Euskadi, Santa Clara County Library and The Regional Automation Consortium (TRAC). Most of them support both iPhone & android. SMS notification services are also used by many libraries to offer library services.

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5   RESULTS AND DISCUSSION

While the desktop computer is of course still relevant, digital media consumption on mobile devices has truly skyrocketed in the past several years. The internet traffic and usage of mobile devices being the highest has shifted the research focus to develop new and enhance existing mobile technology. The effort to improvise existing mobile technology has undergone in all hardware, software and network level. There has been continuous improvement with 1G to 2G and 2G to 3G. With 4G based on ad hoc networking model there is no need for fixed infrastructure operation which requires global mobility features and connectivity to global network to support an IP address for every mobile device which will enable transmission in higher data rates offering reduced delays and new services. Similarly efforts are made to simplify application development for mobile devices by creating new and powerful development platform.

The internet has already had a major impact on how people find and access information, and now the rising popularity of e-books is helping transform peoples reading habits. In this changing landscape, libraries are trying to adjust their services to these new realities while still serving the needs of patrons who rely on more traditional resources. In order to address the user needs many libraries around the world are adopting mobile technology to enhance the library service. As there are many tools and platforms for application development and further there are many services that can be offered using mobile so different libraries provide different services using different platforms as per user needs and requirements. An annual survey conducted by Public Library of Australia shows that technology equipment available in public libraries showed an increase in each category with Tablets showing the highest growth of 127 percent [19]. The same research shows that among the website offerings library apps for mobile devices showed the largest increase. A survey by Pew Internet and American Life project show that notable shares of Americans wider use of technology at libraries such as Apps based access to library materials and programs [20]. When Pew Internet asked the library staff members in an online panel about these services, the three that were most popular were classes on e-borrowing, classes on how to use handheld reading devices, and online "asks a librarian" research services.

Mobile Technology for libraries will impact existing libraries. It will greatly reduce the need of traditional libraries. Setting up a mobile library is easier than building infrastructures and hiring 24x7 working staff for a traditional library. Also because of its benefits most people would opt to choose using mobile libraries over traditional ones. The role and knowledge base of librarian for a mobile library would be

very different than a traditional librarian. The librarian then would be required to be knowledgeable about the technology used for the mobile library. User Environment would also be greatly influenced by the introduction of mobile libraries. It would be very convenient to the users not having to go all the way to library, go through the formalities of issuing a resource then finally returning it. With this there is always a possibility of misplacing the issued resource and loosing it. A user will never face any of these issues while using mobile libraries. The user also need not be physically near the library to issue/return resources. All these factors would help to improve user experience as compared to the quality of services offered by traditional libraries. The user experience can be further improved by adding services like instant messaging for inquiry purpose.

6   CONCLUSION

Mobile applications can support learning processes by making library resources more ubiquitous, by bringing new users to the library through increased accessibility to the resources libraries offer, and by creating a new way to enhance connections between users and libraries. This increased use of mobile phones provides an untapped resource for delivering library resources to users.

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