Mobile Application Research and Development: The African Context

ABSTRACT

The growth in the use of mobile phones across Africa presents many opportunities for applicaiton developers, commerce, socio-economic development as well as academic research. Mobile phones have the potential to transform how people live, interact and transact business. However, Africa also has unique challenges, and will thus not always be simply able to use off the 'app market' applications that may work well in developed economies. Challenges include literacy levels, language differences, and the peculiar lack of supporting infrastructure. Some deployed mobile apps and services are described and contemporary research in mobile apps development is highlighted along with how further work in these areas could benefit African use cases

Keywords

mobile, applications, development, research

1. INTRODUCTION

The rise and rise of mobile phone use in Africa has been remarkable. Developing economies constitute the fastest growing mobile phone market worldwide[22]. A number of factors account for this. Many Africans do not have the alternative option of wired communications, as public switched telephone networks are not widely deployed. Furthermore, the cost of providing wired connectivity across vast open spaces to often impoverished communities is pretty prohibitive (and there is often not a business case). In contrast, mobile wireless access fits the bill for a technology that can be more easily, relatively cheaply and quickly deployed.

The growth in mobile subscriber numbers in developed economies has peaked and stagnated. Services abound for that market of usually tech-savvy users. New applications continue to be developed for these markets, and researchers and developers continue to work to provide additional smarter, more convenient technologies, services and applications. The remarkable growth of mobile phones in Africa presents even more opportunities and challenges for researchers and developers.

There has been a lot of talk about the digital divide between Africa (along with other developing regions) and the developed world. There is not much access by the general population to ICT, to the connected world and to information. The ready availability of mobile phones changes all that. In fact, the digital divide has also been described as the digital difference[5] because with the advent of the ubiquitous mobile terminal, many are getting connected and gaining access to a world of resources and services by their mobile terminals (instead of PCs). Other factors that can affect uptake of mobile services include price, data transmission rates and quality of service, content and language and applications targeted to low-end devices and users [22].

Services may be built around a wide range of bearer technologies depending on the capability of the target phone. Technology enablers include short message service (SMS), multimedia messaging service (MMS), unstructured supplementary service data (USSD), interactive voice response (IVR), HTTP over GPRS (or better), and sometimes WAP.

For many, the mobile is their first and often primary access to the connected world. The mobile web and mobile based Internet access for example is growing around the world and many mobile web users use only their mobiles for this purpose. It is reported [29][34] that as many as 70% in Egypt, and 50% or more in Nigeria, Ghana, Kenya and South Africa who use their mobile phones to access the Internet, only make use of the mobile for web access, or infrequently use a desktop. This is in contrast to 25%, 22% and 19% in the US, UK and Russia respectively who make use of only mobiles for web access. The mobile only users tend to be under 25 year olds, while in the developed nations, they tend to be older people mostly with lower incomes. It is noteworthy that [29] indicates that 85% of these web mobile only web users make use of feature phones. Further, the exact uptake of the mobile web varies from country to country and is related to data traffic costs and network speed [28].

A number of studies have been conducted and data on Africa's use of technology (sometimes in comparison with the rest of the world) has been documented. For example, the 2011 ITU Report [22] indicates that the cost of prepaid mobile cellular services is lowest in Ghana, Tanzania and Kenya and highest in Burkina Faso, Cameroon and South Africa. The percentage of individuals aged over 16 owning a mobile and using the Internet is highest in Nigeria, South Africa and Ghana.

This paper takes a different approach from presenting

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statistics. The objective is to focus on current mobile applications related research and development projects in Africa, or of relevance to Africa and of academic interest, and to identify and analyse common underlying issues. The resulting analysis will, with appropriate allowances for contextual differences, be generally applicable to other developing regions of the world.. This papers is organized as follows: The next section presents an overview of the challenges and opportunities developers for African markets have. A survey of research and development issues of relevance to Africa is presented next. Subsequently, work done at xxxxxxx University xxxxxx is presented. Observations and lessons from these activities are presented finally.

2. CHALLENGES AND OPPORTUNITIES

2.1 Challenges

There are many challenges related to mobile applications, some of which are peculiar to developing economies. For example, there is a comparatively lower adoption rate of mobile data applications in Africa compared to the developed world. One reason is lower literacy levels. This is a challenge that will need to be addressed, possibly using technologies such as text-to-speech, interactive voice response (IVR) and speech recognition. Also, many opportunities exist in developed economies to make mobile applications and services take advantage of the installed infrastructure to enhance user interaction and to provide smarter services. For example, mobile payment systems can be significantly enhanced by complementing and making use of the installed base of payment (and backend) systems. Such an installed base is virtually nonexistent in vast swathes of Africa. To bank the large numbers of unbanked in Africa, and/or to include that population in m-commerce, calls for developing new strategies that will also take account of lower literacy levels in technology and language.

2.2 Opportunities

The many challenges present a great opportunity for apps developers and researchers. The use of mobiles in Africa often has a higher value impact because of the lack of alternatives, resulting in considerable savings on time and cost. Travel conditions are challenging and expensive. Mobiles bring communities together. Timely information on agricultural produce markets can significantly affect the fortunes of a farmer for example. Businesses are getting built around apps development and services. Quite a few startups have built apps suited to African conditions, lifestyle and culture. Money transfer apps and service are a classic example. A report by Hystra [19] notes that starting and sustaining successful mobile based services depends on entrepreneurship and ability to scale requires a multi-stakeholder partnership. It then analyses some success stories in the key mobile based service sectors in developing countries namely healthcare, education, agriculture, and financial services. These sectors affect the population at the bottom of the pyramid. For the large emerging market for apps development and research, similar strategies are required to meet the needs for people at the bottom of the pyramid because their peculiar challenges are similar, irrespective of the particular use case.

3. REVIEW OF DEVELOPMENT EFFORTS IN AFRICA

Some good mobile apps and services have been developed and deployed in Africa. Kenya and South Africa have particularly vibrant mobile application developer communities. Many of these apps try to use ICT for development, and projects have been built around mobile services notably in the areas of health, education, agriculture and financial services. The effort has been development oriented. The following sections review some of what has been accomplished and highlights what may be of academic research interest.

3.1 Education

Education projects try to supplement or complement formal education by providing additional training to those who may need it. Mxit [33] is a popular social networking and instant messaging platform on mobile terminals that is popular with South African youths. It also serves as a platform to encourage the youth to read and comment on stories.

An architecture for enabling call center type functionality to support math education is presented in [6]. It is meant to extend the functionality, scale and flexibility for support of the Dr Math platform [42] by among other things allowing volunteer tutors at any geographical location to provide help to students. Various chat protocols and a variety of bearer technologies over mobile phones are tied together seamlessly to provide this service. An educational dictionary application[17] for kids aged 3 to 7 has been designed and built as an entertaining tool to aid children improve their vocabulary. The teaching is by means of images, sounds and text. The interface is image based rather than just text. Challenges include limiting the overall size of the application to the J2ME upper limit of 1MB, resulting in the use of smaller lower resolution images and limited dictionary size.

Persons literate in one language (which may not be the official language) as well as persons who may not read at all, could make use of text-to-text translation or text-to-speech rendering by using the camera on their phone to read out texts. This requires optical character recognition (OCR). Text-to-text translation has been demonstrated on a contemporary smart phone by employing the camera on a mobile to scan, process by OCR, translate and display on screen the translated text.[13] It is able to take into account perceptive distortion, where the desired text is not aligned horizontally, and the characters are not of the same size. In this particular project, all the processing is done on the phone itself, apart from the text-to-text translation. Further work is needed to improve the speed and robustness of the algorithms employed.

3.2 Health

Africa generally has a low number of health professionals relative to the size of the population. There has been an interest in making use of mobile terminals to extend the reach of health services. Health related projects have often focused on health data collection, remote diagnosis. mPedigree[32] and Sproxil[40] enable mobile users to verify the authenticity of drugs they purchase by scratching off panel and sms'ing the revealed ID to an SMS short code. A response from the service indicates the genuineness of the product. The Grameen Foundation's MOTECH [41] program collects data on infant and maternal health as well as disseminates information on healthful practices. The clickdoc project [9]

tries to offer diagnosis by having a field worker collect relevant data (by answering a questionnaire on the mobile), as well as taking a high resolution photo of diseased area (if applicable). A remote doctor can offer a diagnosis based on the data. It has been applied to dermatology, HIV and malaria cases among others.

Sensors on mobiles may be used to remotely monitor various health conditions. For example, an accelerometer can sense motion and can be employed to provide care services. The motion and exercise regime of a patient can be monitored[50]. describes a project where the accelerometer on a phone is employed along with machine learning to classify movement. Thus if an elderly person suffered a fall this could be determined. Further work is however needed to generalize such a tool. This particular system was trained with data where the mobile was worn on the wrist. It will fail to respond correctly if the mobile is carried on a different part of the body. A generalized adaptive model is desirable, which will also work for different individuals' behaviors.

3.3 Finance

There are many efforts at developing useful mobile finance-related applications. Finance related projects have often dealt with money transfer, mobile banking, insurance and a few new financial services which conveniently take advantage of mobile technology. Its popularity can be attributed to a number factors including the fact that there is a large unbanked population, travel is inconvenient, expensive, dangerous sometimes, and tedious for a modest remittance to people living in a far-off location, and there is a real market need for automating financial transactions. M-pesa [38] is probably the most famous of the money transfer services. Mobile operators on the continent continue to create mobile money wallets, but these have not been as successful in all countries. The platforms are also mostly not interoperable.

Some projects[8] have looked at enabling micro enterprises to get connected and be able to take advantage of e-commerce from their mobile phones. Two mobile applications presented in [17] attempt to help the clients who participate in an incubation program (where they use PCs) to continue to run their businesses when the incubation program ends. The apps use visuals for navigation and interaction rather than natural language words only, since the target audience is illiterate or partially illiterate. An accounting application and a business expense tracker were also built. The challenge was representing abstract concepts and navigation with images that were universal enough so that applications could be used in other countries/settings. User interface designs that are universal enough remains a major challenge.

There are good opportunities for money related applications. The availability of mobile phones in many communities represents a low barrier to entry for mobile based payment systems. Many transactions will be of small monetary value, judging by income levels; so any systems developed should make micro payments inexpensive.

The payment process itself should be simple and convenient. Mohammadi et al[37] describe major payment systems in Europe and note that some systems employ the use of PKI-SIM cards. This offers security but introduces additional cost. It requires users to obtain new SIM cards, and thus requires the cooperation of the network operator. However, the system is compatible with all GSM networks. That paper also describes another system that uses IVR for authentication. Consequently, any phone may be used for a transaction, but has a downside that it cannot easily be used for web based transactions. Also because of the IVR call back, transaction cost could potentially exceed the cost of micro transactions.

Options for deploying mobile payment services are presented and evaluated in [1]. SMS, USSD, Java apps using GPRS, dual SIMs, and SIM based application platforms among others are described. Based on a survey that may be applicable to Iran only, the paper suggests that a SIM-based application with binary SMS is perceived as the best solution. Near Field Communications (NFC) based payments are yet to catch on in many countries but is expected to be the second best alternative after smartcard payments in countries where smartcard payment infrastructure already exists[35]. It is perceived to be a preferred option when compared to other mobile based payment systems. However many current merchant systems do not support contactless payments.

Frameworks for payment systems have been proposed that make use of QR codes, and take advantage of the mobile phone's camera[23] This could be useful since the user may not have to key in many details of the transaction. However, not all phones will have a capable camera.

3.4 UI, UX, HCI

Building user interfaces for data applications for users at the bottom of the pyramid continues to be a challenge. Chipangura et al. [8] implement, deploy and evaluate the usability of a mobile e-commerce application. The primary purpose is to allow members of a cooperative to directly update information on their products online. The clients ordinarily fill out paper forms and submit them to a webmaster because they have no access to computers themselves. The evaluation was however carried out by university students and not the women of the arts and crafts cooperative - the university manages the website and mobile application. Though the feedback obtained is helpful, it will be useful to determine how the computer illiterate people in the cooperative use such an application.

Many African languages can be represented by the Latin character set (or the African Reference Alphabet) [BritanicaRef]. Some work has been done with the Ethiopic character sets which have more than 300 characters. Online handwriting recognition[39], and SMS [2] have been proposed or implemented. There is Unicode support for this script. Most other languages have not fared as well, and more localization needs to be done.

3.5 Other work:

There are a number of agriculture related apps. These are very similar in scope and operation to those in health and education (from a technical perspective). Agriculture projects have often tried to help farmers obtain better prices for their products, or have been information dissemination tools âĂŞ providing best planting times and practices. Essoko [12] brings farmers current market prices and thus enables them bargain for better prices. And farmers in Kenya are reported to use mobiles to engage in similar price finding activity.

Botha et al. [5] propose Mobile4D, a scalable, standards compliant mobile service delivery platform that is bearer agnostic. Services may be delivered over any available access technologies including SMS, GPRS and USSD. The platform

will enable a developer to focus on building reusable service blocks based on business needs, rather than on service architecture, and is targeted specifically towards the needs of Africa. The platform is an execution environment and is built around developing service adaptors for major mobile services, over which services may be delivered.

3.6 Further Considerations:

Many apps are complemented by a website where significant customization may be done. However, this may not work well in Africa, since for most people the mobile may be the only access to the Internet. A slightly different paradigm is needed for many in Africa.

The Hystra report [19] indicates that for some deployments, a human intermediary or local agent is required to interface the target audience and the technology. Such scenarios include applications such as mHealth and Agric. For other applications, crowd sourcing is employed. Ushahidi [45] for example makes use of crowd sourcing for information collection, visualization and interactive mapping. It was initially used to map reports of post-election violence in Kenya

Quite a few mobile apps projects and services have targeted women's groups [41] [17] [8].

3.7 Support for developing apps and services

There has been significant effort at building human resource capacity in the area of developing mobile applications and mobile web in Africa. Different approaches have been taken targeting different strata of the society. MIT's Entrepreneurial Programming and Research on Mobiles (EPROM) Program [11] is targeted at university students. University faculty members from across the continent were first trained on developing mobile apps and services, and were free to adopt and modify a curriculum that had a good breadth of coverage of mobile apps development. This program churns out a good number of graduate developers in mobile applications from universities across Africa. The World Wide Web foundation [44] [14] tries to encourage mobile entrepreneurs by demystifying the technology and training people to build SMS, IVR and web based solutions. The training also includes a business segment on how to deal with operators, regulators, mobile marketing and research and related business topics. The foundation also tries to connect entrepreneurs with organizations who may offer seed money for start ups. It has held a number of training programs in East and West Africa. There are a number of organizations that also provide suitable environments, mentorship, training or space and facilities for entrepreneurs and startups in the mobile space like InfoDev's [21] mLabs, Meltwater Entrepreneurial School of Technology (MEST) [43], and iHub [20]

4. OVERVIEW OF ACADEMIC RESEARCH:

The large and growing mobile market in Africa certainly presents opportunities for business, and for closing the digital gap by being digitally enabled but different. It does also present opportunities for academics to engage in meaningful research that is relevant to the many unique challenges that the use of mobiles in Africa presents.

4.1 Language

One fundamental challenge is language. Africa is vast with populations of people who speak a wide range of languages other than Western languages. West and Central Africa have the highest density of languages worldwide [BritanicaRef]. It remains true that in most countries, one or other Western language is the official language, but many ethnic groups speak their own language. It is noteworthy that many of these persons, particularly the older people can read their own language but not English (or whatever the official language may be). These really are literate. Then there are those who do not read any language at all. Indeed, some languages are spoken by so few that publishers have not printed anything in their languages, not even a portion of the Bible, which tends to be available in many minority African languages. Mobiles present a cheap and ready technology to distribute content in any language. People who fall into these categories could additionally be enabled to interact with the connected world by use of text-to-speech technologies, translation and speech recognition. Clearly, there are many potential benefits in text-to-speech and speech processing technologies. Applications can readily be found in many fields including education [26] [36], literacy, assistive technologies for persons with disabilities [10] and translation etc. Such applications can provide mobile users a convenient alternative means for accessing or providing information[47].

While many text-to-speech (TTS) systems have been implemented for English and a few other western languages, TTS systems are absent for many indigenous African languages. Speakers of such languages stand to benefit greatly from translation and text-to-speech by gaining access to the tremendous volume of content already available online. A similar system has been piloted in South Africa [25] but depends on SMS input. It does not currently support voice recognition as input.

A challenge with developing TTS applications is developing systems that are real time and fast enough using the limited computing resources of a mobile. Further some African languages are tonal. A TTS system for the tonal Thai language has been implemented [49] with Flite [7] [4], an open source speech engine for constrained devices. The objective of further work is to develop more natural sounding speech in real time, at high speed. Strategies for implementation will need to look at optimal selection of diphones from a database as well as complex text analysis, to cater for a wide range of words. Similarly, database compression and code optimization are important. A voice0to- SMS application would also benefit older persons who are currently disinclined to text, the blind, as well as persons who are less tech savvy. A framework to accomplish this has been proposed [24] but not yet built.

Many applications exist that could take advantage of voice recognition systems. There is a body of knowledge in Africa that has not been documented but is passed down from generation to generation by word of mouth. Herbal medicine recipes and other oral traditions fall in this category. It remains a challenge to track knowledgeable individuals in communities to transcribe their thoughts. Crowd sourcing could be an effective solution, but could be even more successful if content can be obtained without the tedium of typing/writing âĂŞ the same reason why documentation does not exist. Audio based wikis for mobiles have been built. Wikis are for shared content creation and access. There are challenges with content creation, editing and integration

with text. Language problems previously described also apply. Reference [25] describes a system that provides an interface to an existing wiki, it takes an SMS query and returns an audio call that reads out the requested document. This work however does not permit content creation. Other audio wikis [30] [27] similarly often serve as information retrieval systems mainly. The ability to annotate or retrieve is challenging and the outlook is to focus on annotating recordings so they can be indexed and searched. An audio based wiki that allows users to add, retrieve and edit audio clips is described in [47] but does not interface with a text based system.

Automatic Speech Recognition (ASR) will be useful in offering voice interaction. However, ASR interfaces are somewhat more challenging to deal with. Speaker-dependent ASR recognizes words better, but needs to be trained by the speaker. These interfaces thus tend to have smaller dictionaries but will work well with its trainer. Reference [46] describes a framework for multilingual speaker independent ASR. While efficient processing can be done in the cloud, there is potential degradation if audio is transmitted over the air interface for cloud based processing [24]. This will need to be evaluated further.

4.2 Location aware and context based services

There is a general lack of detailed maps for many African towns and villages. (There are nevertheless some very fully featured maps for some places in South Africa, Kenya and a few others) Even where maps exist, they are not sufficiently annotated to be useful. These can surely benefit from using crowd sourcing activities to gather map data. Even more important, because of the challenges associated with travel within/between cities, location based services will be particularly useful. Thus far, they appear to have been used mainly for providing location related data. Usahidi [45] has been used to map such things as election violence and disaster conditions. Esoko [12] offers farmers the market prices at various location around a country.

Systems such as these could be extended with additional research work. Privacy while using location based services is an unsolved challenge. Users may like to remain anonymous or keep their current location private. This may be desirable for political, lifestyle, medical or other reasons. A number of strategies to achieve this include placing an anonymizing server between the point of access and the service provider [51] [16] [15]. A location anonymizer however introduces some centralized service which should be contacted in order for one's location to be randomized before the service is rendered. This represents a single point of failure, does not scale, and is subject to potential attack by malicious users, and introduces delays in service delivery. This single point, which should be trusted, will likely hold the true location and identities of all its clients. Distributed environments have been proposed [31]. Using spatial k-anonymity, a user's actual location is transformed into a larger cloaked area and the exact location can not be distinguished from k-1 others. The larger the k value, the higher the anonymity. In general, the query request returns a candidate list of responses which get filtered by the trusted anonymizer, and the precise response is returned to the client. A general challenge with k-anonymity algorithms is that in sparsely populated areas, k is small, and identities can more easily be determined by tracking.

5. OUR RECENT DEVELOPMENT WORK:

The computer science program at xxxxxxxxx includes a course on mobile application development. Students who take this course can immediately find direct application of the knowledge gained in addressing some of the challenges of businesses and communities. The course is loosely based on MIT's Entrepreneurial Programming and Research on Mobiles (EPROM) curriculum [11]. The xxxxxxxxxx course covers topics such as mobile friendly web page/application development, development in Python (for Symbian), J2ME (including a number of user interface frameworks such as LWUIT), Android platform, Flash and SMS applications. Development for apple's iOS is excluded because of the lack of hardware for the development environment. Students who take this course have developed a range of applications, and typically also include a mobile component in their final year capstone project.

A good range of applications have been built. For the last class taught, students were free to develop any product or service within certain constraints: At a minimum, each project must incorporate mobile friendly web pages and technologies. The product/service must interact with an online component. A component to permit SMS interaction was required. This could be by means of a web based content aggregator, an SMS gateway application, or similar. Three mobile applications for the same service were to be developed, but targeting different platforms. A smart phone version (Symbain S60, Android, Blackverry etc), a standard J2ME, as well as a J2ME version that makes use of a User Interface framework for beauty. A two weeks time frame was allocated.

A wide range of applications were developed. The majority of applications were commerce related. Besides the usual PC friendly ecommerce sites developed, mobile friendly portals were created to extend access to mobile users. The inventory and order requests are managed from a mobile app, and clients get notification of the status of their orders by SMS. Clients may also issue SMS queries. Applications and services developed include a hire-purchase shop, a generic mobile market (to permit sales of any items), a shoe sales shop, and sports merchandise. Other business applications include one to permit the placement of orders at a restaurants in advance, and fleet management. There was a project on micro finance in the informal sector that tries to address one of the common challenges locally. This project automates the record keeping and information management part of microfinance operations, and sends clients notification of transactions on their accounts.

A number of applications provide information for clients but are such that a business could be built around them. There were projects on public transport scheduling, telephone phone directory, and an accommodation search service. Few others had a social networking orientation. Two of such examples are a project that allows posts comments and recommendations on body building and one that is a mobile billboard, which receives posts and advertisements by SMS. Previous classes have produced a similar range of projects, as well as games. An example is the oware game played by two mobile users over Bluetooth, or by an individual against the mobile.

Interest in the course remains sustained after students complete it, and it is reflected in the final projects that students carry out. For example, a recent project has tried

to build a java based framework to defragment the mobile development environment. BONDI is a web OS, consists of Javascript extensions, and gives digitally-signed scripts access to phone functions and features . It is a uniform implementation on different platforms but works on smart phones. A project to address the data management issues and some of the bureaucracy and corruption associated with road traffic offences has been carried out. Using a J2ME mobile application, a police officer can book an offender, recording the details of the offence and particulars of the offender. The data is sent to a cental database where fines are administered or processes are initiated for court appearance if needed. Repeat offenders can be easily identified and managed accordingly. Because of the lack of a functional system, policemen tend to withhold the drivers license of an offender themselves, and lends itself to corruption, since most offenders are willing to pay the policeman off to avoid the courts.

An application to minimize the theft of electronic devices has been built. There has been a surge in the theft of devices notably mobile phones and laptops The J2ME mobile application component of the application enables anyone, including small shops without a PC to record identifying details of electronic items sold, bought or owned. (unique details include IMEI or serial number). Ownership can be verified or transferred, and lost items could be reported. However, if anyone registered a stolen device, law enforcement agencies could follow up. Ownership of recovered items can also be resolved. This system will only work if there is mass registration of electronic devices. Home Automation using a mobile phone has been demonstrated in a project. This enables a home owner to interact with devices connected to a home PC by its parallel port. The mobile application gives the user the flexibility of knowing the state of a device from any location as well as the ability to turn on or off that device.

A number of projects target small scale businesses and the mass market consumer. One project builds an online inventory system for merchants to manage their stocks . Another provides a restaurant reservation service. The restaurant does need to have a PC to receive reservations and orders. A church accounting system with components for mobile based income and expenditure management, as well as mass sms messaging for church service reminders has also been developed.One project attempts to provide travel directions in an environment where there are no known street names. This is a common phenomenon in many small towns and cities. The principal condition for this to work correctly (a drawback) is that a few locations in this area must have known GPS coordinates.

A few projects do not target the mass market but are somewhat developer oriented. A project to develop an SQL database for smartphones was built on the symbian platform and prototyped using Python language. Python does have its own database already, but this project still used python as a proof of concept. The work in [3] recognizes that many business transactions and activities that typically make use of a desktop application are actually database applications with basic database record manipulation operations. These can also be adapted for use on mobiles. For the informal sector, large numbers of businesses will need such custom built applications for their operations, but on mobile. It takes advantage of this observation and builds a rapid application development platform for mobile applications. No coding is required to build a application, complete with the required database. An SQL script is generated, along with the PHP pages for interacting with the hosted database, the mobile or a desktop web user, and an error free mobile application that makes use of the standard J2ME widgets are built in one step. The user needs to only specify the fields that will be kept and the data types. This work will need to be extended to allow for inclusion or editing of complex or business specific business logic (without having to directly edit the generated files), customization of the interface generated as well as potential use of non textual navigation. Students in the computer science department have been involved in other projects that started by other teams. The Click Diagnostics, a mobile health social enterprise with its beginnings in MIT's Media Lab had a mobile health data collection tool which they wanted to pilot in selected African countries. However, the application only worked well on Samsung phones with a particular specification. xxxxxxxxx students partnered with the team to implement portions of it so it could scale fonts properly and run well on all J2ME phones. The application was also built again from scratch for the Symbian S60 platform using python and extensions were made to it. The key addition was the ability to take pictures from within the S60 application for upload along with data collected. At other times, the participation has been related to evaluating user experience âĂŞ such as working with Google to testing SMS based query services locally âĂŞ or as volunteers. Students volunteered with a UC Berkeley team to map pollution in the densely populated Accra city using cellphones and a carbon monoxide sensor. There are currently ongoing projects in the areas of health and education.

6. LESSONS

Although all students had been taught to develop for both feature phones and some smart phone platforms, when not compelled to develop for smart phones, they mostly chose to develop J2ME applications. One factor may be familiarity with the language, but students admit that they found python to be more capable, flexible and gave easier access to the hardware features of a phone without much restriction. Student project reports however indicate that in deciding what platform to choose, one consideration was the types of phones the target market uses. J2ME has the widest reach on the local market and cheap phones are available. J2ME also runs on Blackberry devices unmodified. A new generation of students is however excited by the Android platform. Projects in the current academic year will be monitored to determine if there is a shift in focus.

Applications and services investigated have have varied success in different part of Africa. A notable example is the m-pesa mobile money transfer service. While it has been hugely successful in Kenya, it has had limited success elsewhere. There appears to be cultural factors associated with the success in Kenya. Mxit is similarly very popular in South Africa, but not outside it. Clearly, African markets are not homogenous; solutions that work well in developed economies or in some parts of Africa may not work well when replicated.

The range of applications discussed highlights the design choices that a mobile apps developer has: basically the applications requirements (or specifications) versus resources available on the phone. This is illustrated graphically in

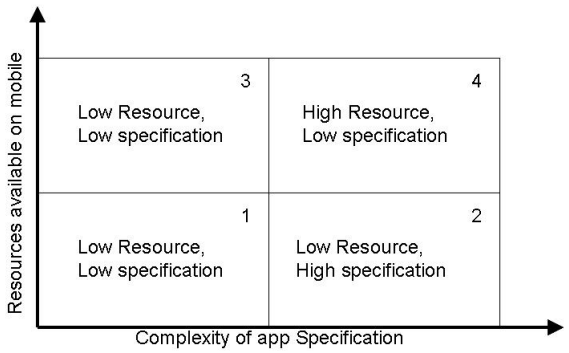

Figure 1: Application requirements vs Mobile terminals capabilities

Figure 1. Quadrant 1: Low Specifications/Low Resources ("Doing less with less"). There are many phones on the market today that are extremely basic, but support SMS. These are usually classified as "dumb phones". Developers have a number of options for creating applications and services. Choices include building applications based on SMS, USSD or use of the SIM toolkit (if the developer works in partnership with a cellular carrier). Alternatively, IVR applications (which require placing a call) can be built. Applications built this way can reach the largest market, although application interactivity is somewhat limited, and there is not much data storage. There are many popular applications and services based on these technologies in many emerging economies such as m-pesa (mobile money)

Quadrant 2: High Specifications/Low Resources ("Doing more with less"): Applications that are more interactive and responsive can be built on mobiles classes as "feature phones". These are not smart phones, but are more capable that dumb phones. These typically have internet connectivity over GPRS, but may lack GPS and other sensor technologies. Most of such phones have a java virtual machine, which inherently places an upper limit on the size of an application that can be developed. Consequently, although these are low resource devices, fairly capable applications can be built. Most of the applications students have built target this platform. Such phones are in wide circulation, and cheaper to obtain. To have a wide distribution, it is wise fit as much functionality as one can on this limited platform.

Quadrant 3: Low Specifications/High Resources ("Doing less with more"). Applications in this category tend to target smart phones, and may be applications that have been re-written for a smartphone operating system- to take advantage of the better integration and multi-taxing ability of the target platform. Some programs in this category also exist simply because they can be created to show off certain capabilities. Nevertheless, there are many very simple applications that do just one thing, but are depended on a sensor or feature that only smart phones have.

Quadrant 4: High Specifications/High Resources ("Doing more with more") This quadrant represents applications at the bleeding edge of technology. These applications will generally run on smart phones and make use of a variety of sensors available to the phone, interact with data and services in the cloud, and offer "smart" services to the user.

First world developers appear to work more in quadrants 3 and 4 while developing world developers often have to contend with quadrants 1 and 2. Casual observation suggests there are more basic and dumb phone on the markets of developing nations. The smaller number of smart phones are expensive, used well by tech savvy persons, and by others as a status symbol. Furthermore, the infrastructure to support applications such as location based services is non existent. Location based applications tend to have limited use in some cities. However, innovative applications can be built to turn this tide around.

Quadrants 1 and 2 and not necessarily bad segments to work in. It is good engineering to try to accomplish more with less or even to use a limited specification in order to reach a wider market. This frugal approach to design often results in leaner faster software [48], and elegant design of Apple products [18].

7. CONCLUSION

It is evident that many opportunities exist in Africa. There are challenges in building apps that impact the Bottom of the Pyramid well. This includes overcoming language barriers by incorporating the use of IVR, TTS and text-to-text translation into applications. Challenges building speaker independent speech recognition as well as managing tonal speech, and speech with clicking sounds will need to be addressed. Privacy in location based services will need to be developed further, particularly in view of Africa's business and political environment. Payments systems based on mobile that take into account micro payments and are very easy to use need to be developed. All said, Africa presents a good opportunity to research solutions and develop apps that fit well the mode of life led by people at the bottom of they pyramid.

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