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SIM or Application Layer? An Implementation-Level Analysis on the use of Mobile Phones for ICT Development

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In recent years, mobile phones have started to become popular in their use as a platform for ICT based development projects. This paper provides an implementation level analysis on the use of SIM card programming and application layer programming. This is a particularly important consideration when the program is to be run in developing nations due to the older handsets that are frequently used. The paper describes the ramifications that each layer would have on the application that is created, in particular in the context of developing nations. It then describes a case study of a development project where we have implemented two such applications, illustrating the principles described in the paper.

1. Introduction

In 2003, the United States Agency for International Development (USAID) defined two categories of Information and Communication Technologies (ICTs): traditional ICTs and modern ICTs [Ruseten and Ramirez 2003]. USAID define traditional ICTs as technologies that are engrained in most people’s daily lives such as television, radio, and fixed line telephones. Modern ICTs are defined as computers and communication systems between computers such as the Internet, desktop computers, laptops, mobile phones and PDAs. There is often great debate amongst researchers about the compatibility of modern ICTs in developing communities [Pade 2007]. Polikanov and Abramova [2003] identify three distinct schools of thought: pessimists who argue that progress in ICTs will only broaden the digital divide; optimists who propose ICTs as the remedy to all problems faced by developing nations; and realists who maintain that societies will adapt technologies to serve them best.

From a realists perspective, Pade notes that it is assumed that traditional technologies are more suitable in meeting the needs of rural communities as they already face challenges such as poor education and illiteracy [2007]. McNamara also warns against overlooking traditional ICTs which in most cases are more appropriate, affordable, and adaptable to local community needs than modern ICTs [2003]. If the only pre-requisite of a technology to be seen as traditional is that it is engrained in most people’s daily lives, we argue however, that due to the proliferation of mobile phones in developing nations, they can now be seen as a viable technology. A report compiled by the Wireless World Forum states that 66% of all South Africans own one or more mobile phone contracts [2006]. Another study compiled by the Consultative Group to Assist the Poor
(CGAP) and United Nations Foundation reports that in early 2006, the mobile phone became the first ICT to have more users in developing countries than in developed ones [Ivatury and Pickens 2006]. Donner [2004] reports that each day, thousands of people in developing nations purchase mobile telephones. On top of this, mobile phones have been used as a platform for development initiatives in a wide range of areas: the fishing industry in India [Reuben 2006]; a telemedicine network for rural clinics in Palestine [Zatari 2007]; online banking in Africa [Dybwad 2005]; and micro-entrepreneurs in Rwanda [Donner 2004]. These figures speak of the proliferation and acceptance of mobile phones within developing nations.

For applications to be available to mobile phone users, they can either be written as web-based applications that require a constant connection to the Internet, or they can be written to be run on the mobile phone. An issue facing many developing nations is a lack of physical infrastructure, including network infrastructure [Dutta 1997]. Although mobile phone reception covers fair portions of developing countries, it can at times be flaky, causing web-based applications to drop their connections. It is for this reason that this research investigates applications that reside on the mobile phone itself, rather than require constant connection to the internet.

Primarily there are two ways that these mobile applications can be run: on the SIM card itself, or as an application that runs on the handset. The major difference between the two techniques is that the latter relies on more capabilities on the handset itself than the former. As in all technologies, there is a roll down in the capabilities supported by handsets, with technologies that were considered innovative (for example the camera) slowly being available on even the most basic handsets. Also, with improvements in memory, processor, screen size, and power consumption, new mobile phone technologies are continually emerging on the market for much the same price as their predecessors. Surprisingly, this roll down of technology is slower than would be expected. In March 2008, Japan became only the second country (behind South Korea) to take delivery of no second generation mobile phones [Agence France-Presse 2008]. This illustrates that even in developed nations, consideration must be made for the capabilities of the mobile phone handsets.

Over the past three years, we have been involved in an ongoing ICT for development research project in a rural area in the former Transkei in South Africa. The research reported in this paper arose after visiting the area for a year and seeing how mobile phones were so ingrained into the lives of the people who lived in the area (see Figure 1). The original objective of the project was to develop and field-test the prototypes of a simple, cost-effective and robust, integrated e-business/telecommunication platform, to deploy in marginalized and semi-marginalized communities in South Africa where a large proportion (42.5%) of the South African population live. The project evolved however to include several other sub-projects, one of which is to investigate the use of mobile phones as a platform for ICT for development.
This paper presents an implementation-level analysis on the use of mobile phones as a platform for ICT for development. It compares and contrasts developing programs on SIM cards and developing application layer programs, given the particular context and constraints in place in developing countries. In particular, this paper references development on Java Card [Sun Microsystems 2008a] platforms and Java Mobile (J2ME) [Sun Microsystems 2008b] platforms. Although they are not the only SIM based and application platforms available for mobile phones, they are the environments that the author has most experience with.

2. Implementation Techniques

As mentioned in the introduction to this paper, there are two levels that programs can be written on that reside on the mobile phone: SIM card level; and application level. SIM card level programs are executed solely on the SIM card and therefore make no demands on the mobile handset capabilities. This makes them particularly suited to older mobile phone handsets. However, as they are limited to the size of a SIM card, they are forced to have a very small footprint and cannot make use of any of the peripheral devices included in the mobile handset. Application level applications on the other hand can take full advantage of any peripheral devices, but as handsets can differ so vastly, may not be suited for as large a variety in mobile phones as SIM based applications. This section will now present a detailed description of the two levels of programming, with respect to the context of creating applications for low end mobile phones.

2.1. SIM Based Programming

Java Card technology allows the development of applications for earlier mobile phone models by targeting development at the SIM card level, making it unnecessary to have support at the application level. The Java Card environment shares the same architecture as the standard Java environment. Due to the limited resources on current SIM cards, Java Card does not support the following Java features: it doesn’t support all primitive types [Oestreicher 1999]; and does not allow the dynamic download of classes. Instead all classes are packaged using a converted to create one executable file. This in turn reduces the size by pre-linking for the execution on the card as far as possible [Oestreicher 1999].
Java Card uses a Kilobyte Virtual Machine (KVM) which provides a basis for the Connected, Limited Device Configuration (CLDC). This configuration defines small, mobile devices with memory ranging from 160 to 512 Kbytes [Helal 2002a]. It is called the Kilobyte VM in reference to the small footprint of the platform [Sun Microsystems 2000]. Java Card has been used for many different purposes: to implement electronic money for e-commerce purposes [Insik and Ingook 2001]; storing presence information for mobile phone address books [Moyo 2007]; and as a store for sensitive data in the context of near field communication [Madlmayr et al. 2007].

2.2. Application Layer Programming

Although Java Micro Edition (J2ME) was released in June 1999 [Helal 2002a], it wasn’t until September 2000 that Java was commercially deployed on mobile phones [Lawton 2002]. By April 2001, over three million Java handsets were sold worldwide [Helal 2002b]. Although not the only application platform available for mobile phones, it has been pushed as the de facto standard on mid-range and high-end mobile phones for the past eight years [Lawton 2002].

Like Java Card, J2ME makes use of a KVM with very similar functionality. A difference is that J2ME allows for user data to be stored in a simple, secure manner by making use of persistent storage, such as record stores. The deployment and installation of Java Mobile applications is straightforward, as it simply makes use of JAR and JAD files which automatically prompt the user to confirm the installation [Sun Microsystems 2000].

3. Case Study

Dwesa / Cwebe is a coastal region located in the previous homeland of the Transkei in the Eastern Cape, South Africa. It has an estimated population of 15000 people living in 2000 households. The inhabitants of Dwesa/Cwebe are traditionally subsistence farmers who depend on their crops for their livelihood [Palmer et al. 2002]. Figure 2 (a) shows a typical Dwesa / Cwebe homestead. The region features a coastal nature conservation park which is owned by the community around a reserve and a hotel. The region has a high potential for eco and cultural tourism due to the rich cultural heritage and the marine conservation project undertaken at the nature reserve. We consider the Dwesa / Cwebe region to be ideal to take advantage of the global upsurge in eco-tourism activities.

The Dwesa / Cwebe region comprises of two distinct communities. The Dwesa people on the southern side of the Mbashe River, and the Cwebe people on the northern side. This delineation is not only geographical, but extends to the philosophical outlook on the underlying world views of the two communities [Palmer et al. 2002]. This introduces an interesting cultural dynamic, with the Dwesa community being more educated and open to change, and the Cwebe community representing a more traditional and static culture.
From a political viewpoint, Dwesa / Cwebe is only the second successful land restitution claim case in South Africa, and the first in the Eastern Cape. We believe that it is therefore an ideal location to use as a testbed for the implementation of ICTs in marginalized communities. Like most marginalized communities, Dwesa / Cwebe suffer from major infrastructure problems including limited electricity availability and connectivity, minimal telecommunication infrastructure, poor quality of the transport infrastructure, but we feel more importantly, sub-standard education facilities. The schools that do exist are also under-funded, under-equipped, and under-staffed. Figure 2 (b) is an example of such a school in the Dwesa region, which even lacks basics such as a roof.

In a recent study of 265 residents in the Dwesa area, it was found that just under half (46.5%) of the residents either own or have direct access to a mobile phone (where direct access refers to access to a mobile phone in their household). Of these, 73% charge their mobile phones at the local school or shop, and 12.5% use either a solar inverter or a motor battery. The remaining 14.5% charge their phones either at the nearest town with electricity (45 minute drive by public transport), at a clinic, or anywhere they can find.

3.1. Siyakhula Living Laboratory

The Siyakhula Living Laboratory (LL) is a joint venture between the Telkom Centres of Excellence (CoEs) at Rhodes University and the University of Fort Hare respectively. The original objective of the project was to develop and field-test the prototypes of a simple, cost-effective and robust, integrated e-business /telecommunication platform, to deploy in marginalized and semi-marginalized communities in South Africa where a large proportion (42.5%) of the South African population live. The project has evolved into an experiment on the adaptation of the Internet to rural areas in South Africa, based on the deployment of ICTs in schools, which together realize a distributed access network [Thinyane et al. 2008]

The current deployment of ICT infrastructure in Dwesa has been concentrated around schools which provide a centralized location, accessible to many villages. This allows us to piggy back on existing societal structures which facilitate community
acceptance, buy-in, and eventual ownership of the infrastructure. Another important benefit of locating computer laboratories in schools is that they are some of the few places in Dwesa that are connected to the main power grid (some local stores and health clinics situated on the main road also have power).

In the introduction to this case study, it was mentioned that the Dwesa / Cwebe region has a high potential for eco and cultural tourism. It is this potential that led to us partnering and training with the local craft initiatives and entrepreneurs. An interesting point about the Dwesa nature reserve is that during the summer holidays, the reserve is full of holiday-makers. In other times of the year, the place is empty. We proposed that with the extra market available online, the entrepreneurs and craft people in the area would be able to sell their goods to a greater market. With this in mind we created an online portal where residents could advertise their goods. In reality, we developed two different front-ends to the portal, one a SIM-based application, and the other a J2ME application. The following two sections describe the applications.

3.2. Mobil-e-Com

Mobile-e-Com [Slay et al. 2007] is a SIM-based application we developed to support second economy entrepreneurship. It was designed as a solution to what we saw as a major gap where current e-commerce solutions for development do not exploit the proliferation of mobile phones among the communities in developing countries. Mwabu and Thorbecke [2001] and Pade [2007] recognize the importance of rural based growth on the route to development. It was with this in mind that Mobil-e-Com was created, specifically to harness the currently dormant entrepreneurship potential of the second economy in rural areas.

Mobil-e-Com uses mobile phones to facilitate e-commerce transactions between sellers and buyers via mobile phone. The framework allows sellers to upload details, and if the phone supports it, photos of their goods for sale. Using their phone they can browse and update their goods already for sale. Buyers can browse via an online web-portal and select items they wish to purchase by adding them to a virtual shopping basket. When buyers check out their purchases, the framework forwards the buyers contact details to the seller. It is then up to the seller to contact the buyer to arrange details such as delivery and payment. An add-on to the Mobil-e-Com application is the optional micro-payment infrastructure that can be used to pay for their goods.

As mentioned earlier, Mobil-e-Com was developed to be sufficiently deployable on the SIM card of entry-level second generation mobile phones. Mobil-e-Com could have easily been developed as a J2ME application, but this would necessitate Java support and capabilities on the handsets, reducing its accessibility from the older generation of mobile phones.

Excluding greater support for older mobile phones, there are four other benefits to deploying the solution on a SIM card: independence from the handset; alliance with mobile operator’s network; minimal resource utilisation; and ease of deployment. By deploying Mobil-e-Com on the SIM card, it makes it independent of the handset, ensuring operational consistency. In effect, this ensures that the program will work in
an identical fashion across different handsets. This is important when considering the effects caused by a poorly designed (or poorly displayed) user interface. Assuming the user interface undergoes user testing before it is released, this guarantees the same user experience across mobile handsets. By providing a SIM based solution, the application is implemented with the architectural framework of the mobile operator's network. This allows for optimizations on data transport protocols used, and allows access to operators’ servers (messaging, authentication, etc). Mobile phone resource utilization is also minimal, as the application runs entirely from the SIM. This is important, particularly for older phones, as the resources on the mobile phone handsets are low to start with. Finally, when using SIM based applications, deployment is undertaken using Over The Air (OTA) messaging infrastructure on mobile networks [Gemplus 2006]. This is particularly useful for rural, marginalised and isolated communities. Using OTA, applications, new updates and services can be transferred to mobile phones or SIM cards by the network operator. This allows applications to be downloaded onto a SIM card without physically having to connect to it. By having an OTA backend, the operator’s servers send requests through an OTA gateway to the mobile phone. The mobile phone user then pulls then accepts the request and downloads the application.

Mobil-e-Com was developed using GemXplore Developer [2007], a SIM application development toolkit. For this prototype, there was no network operator buy-in so testing was undertaken using a simulator. EasyOTA [Gemplus 2006] was used to test the OTA transfer and communication between the SIM card and the (simulated) network operator.

3.3. Java-e-Com

The Java e-Commerce platform, Java-e-Com was developed using J2ME for newer mobile phones. In contrast to Mobil-e-Com, this application was designed to be run on the mobile phone itself (rather than the SIM card). It was however designed for the same conditions as Mobil-e-Com. The remainder of this section highlights the benefits that developing on the application layer brings to Java-e-Com, paying particular attention to grounding it in the same physical environment as Mobil-e-Com.

As with SIM based applications, a J2ME application provides portability and interoperability to the user. One application can be developed and executed on different types and varieties of handsets. Also, a link to a J2ME application can be transferred to the handset via OTA and then be downloaded from the Internet and installed on the phone.

The primary benefit of an application layer program is in strict contrast to the SIM based application: it can have greater access to the mobile phone functions and peripheral devices such as cameras that come as part of the mobile handset. Another important benefit of an application layer program is that the J2ME provides a more complete implementation of the J2SE, and therefore supports richer applications than the Java Card alternatives. This provides programmers with more leeway to create graphically rich and attractive applications. This can be a very useful extension, particularly when considering that large parts of developing countries suffer from semi-literacy and
illiteracy [Terryn 2003]. This supports work such as that undertaken by Indrani, Aman and Kentaro [2006], where graphically rich interfaces were created to support illiterate and semi-literate users.

4. Conclusion

This paper has compared SIM based programming with application layer programming within the context of ICT for development. It has highlighted critical considerations that need to be made when programming for these conditions, such as lack of network infrastructure, but more importantly older mobile phone handsets. It has shown how applications can be created particularly for these environments using SIM based programming that make very little demands on the physical phone handset. To properly illustrate the difference this has to programming for other contexts, it paralleled the discussion of SIM based programming with a discussion of a J2ME application.

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