USSD: The Third Universal App

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ABSTRACT

In this paper we argue for the use of Unstructured Supplementary Service Data (USSD) as a platform for universal cell phone applications. We examine over a decade of ICT4D research, analyzing how USSD can extend and complement current uses of IVR and SMS for data collection, messaging, information access, social networking and complex user initiated transactions. Based on these findings we identify situations when a mobile based project should consider using USSD with increasingly common third party gateways over other mediums. This analysis also motivates the design and implementation of an open source library for rapid development of USSD applications. Finally, we explore three USSD use cases, demonstrating how USSD opens up a design space not available with IVR or SMS.

Keywords

USSD; SMS; ICT4D; M4D; mHealth; mAgriculture; mBanking

1. INTRODUCTION

Mobile phone applications have tremendous impact in global development across the domains of health, agriculture, education, and finance. The field, referred to as Mobiles for Development (*M4D*), builds upon the ubiquity of mobile phones and standard digital telephony. Two fundamentally different approaches are used for deploying services on mobile phones. One approach is to build services using generic features provided by the mobile operator, such as voice or text, ensuring the service is available on every single mobile phone handset. The other approach is to take advantage of capabilities of specific types of handsets, including installing and executing applications on individuals' mobile phones. Both of these approaches are important, but in this paper we focus solely on the first approach, targeting applications which are intended to have broad reach and high coverage across a population. One strength of this generic approach is that it can be used to reach people owning basic mobile phones. Even though smartphones have a growing market share, a very large number of people will continue to use basic or feature phones over the next decade. Being able to reach owners of basic phones is particularly important for development initiatives reaching the poorest people.

Mobile applications designed to work with carrier provided services, and not utilize features of specific handsets have generally focused on voice through Interactive Voice Response (IVR) and text through Short Message Service (SMS). IVR and SMS are *Universal Apps* in that they make services uniformly available on every mobile handset. There is a third option for a Universal App, which is less frequently used in M4D: Unstructured Supplementary Service Data (USSD). USSD is a protocol defined inside the Global System for Mobile Communications (GSM) standard.[1] USSD is a session based protocol, like IVR, that supports the exchange of text data, like SMS, thus filling a gap in the M4D design space. The most common uses of USSD are for customers interacting with a carrier's services, such as querying airtime or subscribing to information services. This is done by sending a *star code* (such as *144# to check an airtime balance with Safaricom in Kenya) and accessing interactive menu systems. USSD has a number of advantages over SMS, such as providing greater privacy, which makes it a candidate for some important M4D applications. However, until recently, it has been very difficult to deploy USSD applications due to requirements of working directly with carriers. As third party companies have begun making USSD services available, there are growing opportunities for M4D to utilize a new Universal App.

In this paper we explore the application design space for USSD by identifying fundamental considerations and trade offs between IVR, SMS, and USSD. By analyzing existing universal applications we propose methods for USSD to enhance and improve M4D services such as data collection, health messaging, and accessing data. Based on these findings we describe the design and implementation of a library for rapidly building USSD applications. Finally, we develop three detailed use cases to show how USSD applications in different domains provide services that neither SMS or IVR alone can accomplish.

2. BACKGROUND

Prior use of USSD in the ICT4D literature has been limited. A search of the ACM Digital library returns only 52

[1]USSD is not supported on CDMA networks, however GSM covers 90% of the world and is particularly ubiquitous in those regions with the lowest smartphone penetration.

ACM DEV 2015, December 1–2, 2015, London, United Kingdom.

DOI: http://dx.doi.org/10.1145/2830629.2830645 .

publications using the term "USSD". In two of these publications USSD is either an unrelated acronym or a typo, and 12 of the papers are systems or security papers not related to ICT4D. Of the remaining 38 papers, 32 reference USSD in an incidental manner, leaving only 6 papers with any discussion of USSD in an ICT4D context [19, 18, 37, 17, 38, 23]. Several works have explored the potential of USSD based menus noting that they are feasible in countries using a Latin based scripts [19] but not those that must access the full range of Unicode characters [18]. Based on observations in Kenya, Whyche and Murphy [37] strongly advocate for USSD as a mechanism for reaching the users at the bottom of the pyramid. However, they also note that USSD is not as widely used as SMS or IVR.

Despite a lack of USSD examples in academic deployments, USSD and similar tools such as SIMapps[2] are integral to large scale M4D successes. Perhaps the most well known example is mPesa in Kenya. The wide spread adoption of it and other mobile money programs demonstrates the potential of simple menu based services to reach owners of low-end mobile phones. One reason USSD has not been a primary focus of ICT4D researchers is establishing USSD service has traditionally been more difficult than using SMS or IVR. With SMS and voice, a modem or mobile phone can be the gateway between application logic and the telephone network; however, with USSD a direct connection with a mobile operator (MO) must be established. Most MOs do not support API's with general access, requiring connections through telephony protocols such as Short Message Peer-to-Peer (SMPP) or Signaling System No. 7 (SS7), which have high start up costs and bureaucratic overhead.

However, recently third parties have begun opening up USSD gateways. The APIs have HTTP end points for establishing new USSD sessions and interacting with ongoing ones. Each time a new request comes, the gateway will forward it to all callback URL with the message, phone number, and session ID. The web service is responsible for responding with a correctly formatted message to display. This makes creating USSD applications no more complicated then IVR or SMS. Besides HTTP gateways many software as a service (SaaS) cloud hosted solutions have appeared. These services already connect to existing gateways and have interfaces for creating and managing contacts, messaging campaigns, and data collection flows. However, none of these companies currently support higher level USSD features such as menu creation, managing state, and storing personal information. Table 1 lists some of these gateways, split into gateway only providers and SaaS solutions. This is not a comprehensive list and many similar gateways can be found with global coverage or local focus.

There is a large body of work showing that universal applications built on top of SMS and voice have a significant part in the ICT4D design space. These projects have shown how universally accessible mobile applications can be used as a catalyst for change and demonstrate the role USSD plays in this design space. One of the first ICT4D projects showing the potential of SMS to simplify interactions and reach end users was Warana Unwired [36] which converted a kiosk based information system into an SMS query system. Since then many more projects have explored the SMS M4D design space which we will analyze in Section 3.

Within the field of mHealth there is mounting evidence for the importance of SMS and IVR at engaging patients to improve health outcomes. WelTel [16], one of the first SMS based mHealth studies, showed that sending simple, single word SMS messages significantly decreased HIV viral load among ART patients. Following on this work other projects have shown that IVR can offer a richer user experience for patient engagment [14, 22].

Besides messaging, another major use for IVR and SMS solutions has been data collection in the field. Patnaick et al. [25] did an early study in India comparing forms, SMS, and voice and showed that while voice was the most costly it was also more accurate than SMS prototypes. However, Danis et al. [7] showed that SMS based surveys were successfully answered in Uganda. One reason for these seemingly contradictory results just one year apart is the different demographic and cultural context between Uganda and Gujarat, India.

3. UNIVERSAL GSM APPLICATIONS

SMS, IVR, and USSD can be considered universal applications since each protocol is outlined in the GMS specification and works on every single handset. Universal mobile applications are well suited for M4D deployments that aim to reach end users. There is no need to customize applications for individual handsets as J2ME deployments require or provide standardized hardware to all participants, both of which hamper the ability of a project to scale and reach all target users [28]. The use of these communication channels represents a fundamental trade-off between universal access and the richness of user interactions due to the limited user interfaces of universal applications. In the next two sections we explore the design space of universal M4D applications showing how USSD complements existing services. We also layout guidelines that assist organizations starting M4D projects to decide on which technologies suite their design goals and project requirements.

3.1 Design Space and User Interactions

We first analyzes applications built on top of SMS and IVR to understand the types of user interactions and platforms in use. Fogg and Allen [9] identified five categories of SMS applications for health. Even though this work did not focus on a developing world context, the universality of SMS means it can be applied across applications in the M4D domain and onto other universal modes of mobile communication.

Projecting Fogg's persuasive SMS computing model onto the existing literature we examine well known projects and identified five specific application domains for M4D services. In each of these domains there is a substantial body of work demonstrating the effectiveness of both SMS and IVR. USSD has not been as widely adopted, but the few examples of USSD applications show that it is well suited for complicated user interactions.

3.1.1 Data Collection

Data collection is an important domain for ICT4D acting as an enabling tool to improve service delivery and evaluation. For projects that can provide smart- or feature-phones, there are powerful data collection applications such as ODK

[2]Built on the SIM Application Toolkit SIMApps interface directly with the SIM card enabling menu driven interactions. See Medic Mobile for an interesting use case: https://medicmobile.org/tools

Table 1: **Third party REST gateway providers and SaaS companies.**

HTTP Only Gateways	SMS	IVR	USSD	Coverage
Twilio†, Nexmo^	✓	✓		World Wide
txtNation±	✓	✓	✓	World Wide
Infobip	✓	✓	✓	9 different countries
Africa's Talking‡	✓	✓	✓	Kenya
Ideamart#, SMSGH%, Panacea Moible$	✓		✓	Sri Lanka | Ghana | South Africa

†`http://twilio.com/` ^`http://nexmo.com/` ±`http://txtnation.com` ⋆`http://infobip.com`
‡`http://africastalking.com` #`http://ideamart.lk` %`http://developers.smsgh.com` $`http://panaceamobile.com`

SaaS Enabled Gateways	SMS	IVR	USSD	Coverage
VumiGo§	✓		✓	11 countries across Africa
Voto Mobile¶	✓	✓		Ghana, Tanzania, South Africa
TextIt♣	✓	✓		Android, Twilio
Telerivet◇ Frountline Cloud♠	✓			Android, Twilio, Nexemo

§`http://vumi.org` ¶`http://votomobile.org` ♣`http://textit.in/` ◇`https://telerivet.com` ♠`http://frontlinesms.com`

Collect [13] and CommCareHQ. However, when data collection is required across large populations or must be accessible on personal mobile phones, default GSM solutions are the most feasible option. In this case the universality of SMS, IVR, and USSD trumps the improved UI and features of device specific applications.

While, SMS has been a common choice for data collection, the unstructured and asynchronous nature requires special syntax for submitting data. In the SMS for Life project, weekly SMS reports were collected containing stock levels for antimalarial medications and rapid diagnostic tests in rural Tanzania [4]. Each tracked resource was assigned a single letter code. By combining these codes, all necessary fields were reported in a single SMS. This allowed structured data to be automatically parsed from incoming SMSs. Data showed a high average response rate (95%) and low average error rate (7.5%) indicating that, at least in rural Tanzania, simple SMS reporting is feasible at large scale.

Beyond simple data collection, various methods have been developed to capture large amounts of structured data via SMS. Using a RapidSMS based system, Assiimwe deployed reporting system that captured weekly disease counts and stock levels [3]. With almost 40 data fields, a single SMS per field was cumbersome and expensive, while putting all fields into a single SMS was complicated. Instead, four different SMS messages were created with the assistance of a paper job aid. This eliminated much of the syntax while maintaining an average error rate of 8.8%. Other examples of job aids assisting message creation include the Reporting Wheel from Instedd [3] to help translate data into nine digit numbers for easy submission and parsing.

SMS data collection can also be accomplished with a multi-SMS survey form. This type of data collection is exemplified by early work from Text for Change sending HIV related quizzes via SMS in Uganda [7]. Each question is a single SMS and participants are asked to respond with a question specific key word prefixed to their answer. These multi-SMS surveys have been standardized as part the SaaS IVR and SMS services from Table 1 as well as services dedicated to data collection such as CommCareHQ.

Voice data collection is a good option for low literacy users [18]. Previous results have shown that voice data collection can be more accurate than both SMS and digital forms [25]. Using an IVR system numeric and multiple choice questions can be recorded using Dual Tone-Multi Frequency (DTMF) touch tones and open ended verbal responses can be recorded for later analysis. Multiple projects have used IVR for data collection [11, 15] and just like with SMS, third-party SaaS services have emerged to provide voice data collection.

By using USSD for data collection, the user experience and work flow can be improved in three ways. First, including all transactions in a single session simplifies the user experience around multi-SMS forms. Second, the menu system acts as a built in job aid eliminating the need for complex syntax to fit as much information as possible into a single SMS. Third, using USSD for data collection allows for immediate data validation during the session flow. These advantages of USSD are most helpful for organizations who can not train all end users or when data collection may happen infrequently and enumerators never have time to become comfortable with complex SMS syntax.

3.1.2 Messaging for Awareness

Messaging for awareness and engagement was a cornerstone of Fogg's persuasive technology SMS framework and has become an integral aspect of ICT4D work. The theory behind messaging campaigns is grounded in behavior change communication and relies on two main assumptions: (1) open communication channels improve uptake of available services and (2) frequent small reminders help with the adoption and maintenance of new practices.

The Kenya WelTel project was among the first controlled studies measuring the effectiveness of messaging for awareness [16]. For 12 months patients initiating antiretroviral therapy (ART) received a weekly SMS with the single word *Mambo* (How are you). They were asked to reply with either *Sawa* (Fine) or *Shida* (Not Fine). Even with such simple messaging content, the WelTel study found a significant decrease in HIV viral load between those receiving and not receiving SMSs.

The low cost, quick content creation, and ease of sending SMSs has meant many other projects use it for awareness and engagement. Across the medical domain, projects focused on both health workers [39, 3, 8] and patients [27, 30, 26] have demonstrated high levels of engagement and changes in behavior. In places with low literacy similar

[3] http://instedd.org/technologies/reporting-wheel/

projects have targeted maternal health outcomes using voice such as making automated voice calls from a doctor to pregnant women about iron supplements [22].

A review paper on mHealth found that one reason to prefer IVR over SMS is to ensure privacy for vulnerable populations [12]. For example, a project working with men who have sex with men decided to use voice calls instead of SMS primarily to ensure messages were not saved on shared phones. Recent work with HIV positive youth in Kampala, Uganda has shown that privacy is paramount when sending SMSs [29]. In this respect USSD has the same level of privacy of voice based systems. By requiring a PIN before accessing medically sensitive information, a USSD system can more directly address individuals needs while at the same time protecting doctor patient confidentiality - especially if the phone is shared among individuals.

3.1.3 Accessing Information

Ubiquitous, on demand access to information is one of the most revolutionary features of mobile computing. Enabling end users at the bottom of the pyramid to find information when they need it has been a major challenge in ICT4D. An early project using mobile phones for information access was Warana Unwired [36] which replaced a PC-based kiosk system for information retrieval with an SMS interface at a sugarcane cooperative in India. This system used a smartphone connected to computer to allow correctly formatted SMS queries to access information previously only accessible via a computer. Another ICTD project enabled SMS querying of taxi arrivals in Kyrgyzstan [2]. One finding from that work was that USSD would be more cost effective and user friendly.

The fact that SMS is always available has been a major driver for query based systems. Google and Yahoo both had SMS interfaces [31] prior to more data intensive and graphical interfaces enabled by smartphones. The limiting nature of the SMS responses has lead to work optimizing for this low bandwidth channel [33]. Chen et al. created an SMS based web search system specifically designed for SMS results on low end phones [5]. Voice channels have not been used for data querying largely due to the fact that automatic speech recognition does not work well for the vast majority of languages in the world. The primary use case for voice channels has been to create call in hot-lines accessing information through a live operator [6] [25].

Creating applications for information access over USSD adds a layer of interactivity to SMS based systems. For example in a series of prompts the Vumi Wikipedia Zero application[4] allows the user to narrow down a search before returning the first 180 words of the page and section requested. With the user interface of USSD a sugarcane cooperative could provide a menu driven application for accessing individual information as well as a query interface for in formation about best practices or new procedures. Like SMS, USSD works best with short text based responses and requires the development of backend processes specifically designed for this limited channel.

3.1.4 Social Networks and Group Messaging

Since the first Usenet newsgroups, ICT has been connecting individuals, friends, family, and the larger community. It is no surprise that ICT4D research has looked at connecting beyond the default capabilities of SMS and voice. Odero created Tangazo, as a group messaging platform. Subscribed users could send either voice or SMS messages to custom made groups, and a special SMS syntax was used to manage group membership [21]. Safaricom in Kenya has a small SMS based group SMS messaging service called Semeni[5] that allows users to create groups of up to 10 members managed through a USSD interface.

USSD as a user interface is well suited for small group social networking. Using our library it would be possible to easily create digital groups connecting and strengthening existing community ties. Grassroots community groups are a common mechanism for development. For example, community health workers lead mothers groups and peer HIV support groups and peer structures are fundamental to microfinancing. A USSD menu system could be used to help facilitate group interactions outside of meetings as well as connect different groups.

While Tangazo connected small groups together IVR systems such as CGnet Swara [20] and Avaaj Otalo [24] create voice networks linking large groups of people. At scale curating user submitted content for access over menu systems becomes an issue [34]. In a large USSD based social network similar concerns would arise since search and discoverability are limited to 180 characters. For this reason, we see the benefit of USSD in the social networking domain primarily to help create small focused community based groups.

3.1.5 Complex User Transactions and Interactions

A paradigm shift occurs once useful functions can efficiently and economically be preformed on a mobile device. The mobile is transformed from a one-to-one communication tool into a device for accomplishing tasks and interacting with larger systems. However, it is when complex tasks need to be preformed that the fundamental limitations of universal GSM applications make systems overly complicated. For example, findings from an SMS based agriculture trading system in Uganda showed that almost all the messages received could not be automatically parsed [32]. Again,the study authors suggested that USSD would be a viable alternative to the complex SMS structure.

Because of their session based nature, both IVR and USSD are more suitable for preforming complex user interactions. Many MOs have IVR systems that allow users to top up via DTMF key presses and perform basic administrative features for prepaid lines. One of the most complex IVR universal applications deployed is TAMA which provides treatment support for HIV+ individuals and was tested in India for 12 months [14]. Protected by a PIN patients receive calls from TAMA with reminders to take medication. The system also has the ability to record adherence. Patients can call the system to inquire about symptoms or listen to 30 second health tip messages.

Another example of complex transaction tasks via GSM applications is a pilot project to book train tickets sponsored by the Indian Ministry of Railways [1]. This services is offered on all three universal application GSM channels. The SMS message syntax is quite complex, requiring one SMS with train and station codes plus a correctly formatted date and a second SMS to confirm and authorize mobile billing that has five unique fields. This is in contrast to the USSD interface consisting of a series of menus to select a station,

[4]https://github.com/praekelt/vumi-wikipedia

[5]http://www.semeni.co.ke/

date, and ticket type. Authorization of mobile billing with PIN code occurs within the same session and confirmation details that act as an eTicket are sent back via SMS.

3.2 Advantages and Limitations of GSM User Interfaces

In this section, we analyze the three universal GSM applications from the view point of organizations wanting to deploy M4D solutions and the users they target. When launching a mobile based project the choice of underling technology is dependent on many factors including, but not limited to, target demographics, administrative overhead, usability, setup costs, maintainability, and scalability. There is no universal method or technology set for a mobile based project and each deployment must be evaluated individually, based on the target country, demographics and partners.

3.2.1 Setup and Infrastructure

When starting an M4D project the first question an organization must ask is what technology is available. Connecting with the telecommunication system can be difficult with two main pathways. At the do-it-yourself (DIY) level, a commodity phone can be used as a modem. With tools such as IVR Junction [35] and FrontlineSMS, a working system can be setup relatively quickly and with low overhead. However, these solutions do not scale well. A more robust solution is needed if simultaneous voice calls must be handled or a high rate of SMS need to be sent (over 1000 SMS/hour). A second limitation of DIY solutions is the inability to have toll free numbers and short codes. So, while setup up costs might be low, it is expensive for end users. Projects often look for ways to send airtime reimbursements [10]. There is also a reliability concern for DIY solutions, since the phone-modem is a single point of failure, risking running out of power or airtime, or loss through damage or theft. DIY solutions are not available for USSD, which is a major reason why USSD applications have been limited to large organizations.

At the next level of complexity, there exists an ecosystem of third party gateways who have partnered with mobile operators (MOs) to make available HTTP gateways for voice, SMS, and USSD. Table 1 lists eight of these gateways in two different categories - large multinational and smaller country specific gateways. The multinational gateways can reach many countries because they send messages from international numbers into countries where they do not have a partnership with an existing MO. This makes prices much higher for places like Kenya and Ghana using Nexmio over local gateways that have direct deals with country MOs. In the last few years the the number of these gateways that offer USSD APIs has been rapidly expanding and this is a significant motivation for this work. We expect more USSD gateways to open up in the future. For example InfoBip claims that USSD services will soon be available in Brazil, Peru, India, Thailand, and Ukraine.

3.2.2 Communication Channel Usability

Each GSM transport layer creates a different user experience and choosing the appropriate one depends on the target audience and service complexity. Figure 1 groups each channels based on the mode of communication and the method of interaction. On these axes SMS and USSD are the text based analogs of automated voice calls and IVR. From this

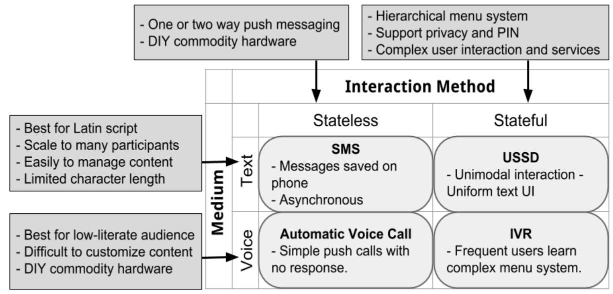

Figure 1: Comparison of GSM applications design space split by communication medium and interaction method.

perspective USSD can be viewed as a bridge between the session based features of IVR and the text based mode of SMS.

There are four primary considerations for choosing between text and voice channels. The first, and primary reason, is that for most projects creating and collecting text based content will have lower administrative cost. For example three hundred preconfigured text messages can be modified with the name of sender and recipient when sending an SMS [26], prerecording these as voice messages means content is not as flexible or customizable. This is a major reason to favor text over voice solutions. However, the second consideration is the literacy proficiency of the end users - which may require that voice be used. A data collection program used by trained CHWs can use SMS [3], while, a program targeting pregnant women from a Mumbai slum should use voice [22]. Another reason to potentially prefer voice over text is that non-Latin script support on low end phones is often poor [17]. Lastly, it is important to consider the bandwidth and cost requirements of each channel. While SMS and USSD have extreme character restrictions (160 and 180 chars respectively) they can easily scale to many thousands of messages an hour. Voice, on the other hand, scales well with larger content but establishing multiple simultaneous voice lines raises costs. Such concerns are very dependent on each country, for example voice is cheaper relative to SMS in India while it is the reverse in Kenya.

3.2.3 Stateful and Stateless Messaging

The requirements of an individual project will also require a decision between the session based interaction which maintains state, and stateless automated calls or SMS messages. Stateful applications allow for a broader design space but come with increased setup and maintenance cost. If an intervention simply needs asynchronous messaging there is no need to move beyond SMS or automatic voice calls. The SaaS SMS solutions from Table 1 have a backends that simulates stateful connections over SMS in the same way web servers convert HTTP from a stateless to stateful protocol.

However, for certain applications the true session based interaction of USSD and IVR cannot be mimicked. First, session based interactions are not saved on the mobile phone. This is extremely important for guaranteeing privacy from friends and family, particularly when a shared phone is involved and sensitive health topics such as TB, HIV, or family planning are discussed. An additional layer of privacy is gained by entering a PIN before taking any actions. Although not secure against man-in-the-middle or operator snooping, this is secure against friends and family from learning about a sensitive medical condition. Other reasons to prefer a session based medium are that hierarchical menus are much easier to implement, real time validation is smoother, and interactions happen in real time.

4. USSD LIBRARY DESIGN

We next describe our library designed to create USSD based applications that work with existing third party USSD gateways. The library is created with the Django web-framework facilitating integrating with Python based message routing platforms such as Vumi and RapidPro. The intention behind this open source reference library is two fold: first to help define the building blocks of generic USSD applications; and second, to provide M4D deployments targeting end users a third option besides SMS and IVR. Currently, the intended user of this library is an organization that has accesses to programming experience, but we are working on methods to create USSD menu systems and questions using Excel worksheets or a graphical flow visualizer. Eventually we hope that third party SaaS messaging providers will incorporate these USSD features into the services they provide.

The library is a set of Python class that can be extended to quickly implement the flow and organization of a USSD menu system. By extending the basic *USSDTransport* class applications with the particular variables required by a third-party USSD HTTP APIs our framework assists with establishing text based sessions. Currently our prototype implementation interacts with the Ideamart USSD simulator[6] (Figure 2) and the Panacea Mobile USSD gateway[7] via their HTTP API.

Unlike stateless SMS applications a USSD application must maintain the users state throughout each session. Both Panacea Mobile and the Ideamart USSD simulator interact over the stateless HTTP protocol, so an important feature provided by the library is the seamless management of session state. This is done by using the session ID provided by each USSD gateway API as a UUID for a Django HTTP session. In this way each initiated USSD session maintains its own current position and state on the server side and can determine the next USSD screen to send based on the current state and user input.

A USSD applications is defined by a linked graph of nodes called *USSDScreens*. The most basic node is a TextNode that simply renders a template string to be sent to the user's phone. Each screen is rendered using context variables associated with the current session and user. For example if each contact has a next visit date, preferred language, and age variable linked with them these variables become available in template strings. Two additional nodes extend from TextNode. The MenuNode links other nodes together attaching numbered options that map to other USSDScreen instances. MenuNodes provide consistent navigation throughout the library; the numbers one through eight jump to a next node while '0' goes to the last screen, '9' goes to the next screen of a long list, and '#' will go back to the home screen. The characters for all of these actions are easily configurable and can also be disabled on individual screens. We also implement the QuestionNode, which validates response and establishes branching logic for the next node based on the response making it possible to create simple forms with a few Python classes. For more specific applications the TextNode class can be extended.

[6] www.ideamart.lk/idea-pro/ussd

[7] www.panaceamobile.com/gateways/ussd-gateway/

Figure 2: Left: Example Maternal Health USSD application running on IdeaMart USSD Simulator; Right: USSD home screen for Indian mobile operator BSNL.

The library also has optional screens that can be added before the home screen is shown. This can be used to present the user with the option of initiating the USSD session where they left of last time or requiring that a correct PIN number be entered before the home screen is shown. Because the USSD library is built on top of the Django framework it also makes it easy to have a web accessible admin interface. Administrative tasks include replying to messages left by users in the USSD system, monitoring usage statistics, and exporting collected data. The library also makes it easy to open a web accessible front end that mimics the workflow of the USSD system. Thus users who have a data enabled phone can access the application over USSD or a web browser. We are also working on an Android application to access the same information over a built in API. Using this library we have built a prototype Maternal Health application for testing the work flow and integration of the libraries building blocks. (Figure 2)

5. USSD USE CASES AND PERSONAS

In this section we explore how the building blocks of our USSD library can create applications that improve the usability and quality of universal GSM applications. These use cases illustrate several advantages of USSD over SMS, practicality when it comes to real time interactions and privacy. Although some parts of these services have been implemented with SMS or IVR, the full USSD implementation is not replicable on any other default GSM medium. They also highlight how the general flow of USSD applications is easily extended beyond the traditional financial services application. However, they also expose limitations of basic GSM applications and why for some cases it might make sense to target phone specific applications utilizing a data channel.

We introduce each use case through a target user's persona and demonstrate how she or he would utilize different USSD applications to accomplish tasks and access services.

5.1 Maternal Health

Mercy is a 20 year old Ugandan living in the informal settlement of Namuwongo, southeast of Kampala. She is among the ninety percent of Namuwongo residents living on less then one dollar a day. Twenty-two weeks into her first pregnancy she has just attended her first antenatal care visit. There was a two and a half hours wait before she had twenty minutes with a nurse who took vital signs, listened to the babies heart, and drew some blood. Mercy was ushered into a room with twelve other first time mothers where they were told what to expect during pregnancy, where to give birth, and given booklets to record clinic visits and their baby's milestones. She thought she was done after this session, but the nurses sent her to another room - this time with just four other expectant mothers. In this room Mercy found out she was HIV positive.

There was a torrent of information and although the nurses tried to be understanding Mercy found it difficult to focus on this new reality. The nurse asked her for a four digit personal identification number so she chose the last two digits of her and her sisters birth years. They told her that if she called a special number - it looked like a code to top up a phone - she could enter her name and the secret number to access information and ask a nurse questions. Before leaving each of them practiced logging into the system.

Later when Mercy tried the system she liked how the first screen did not mention HIV or being pregnant, rather it displayed a generic health tip with a box to type her name. After hitting send a new health tip displayed with another box, Mercy didn't know what to do with this box so she just hit send again. This time the system told her she had used her two health tips and to call again. That reminded her what the second box was for, her PIN number. After correctly signing in she was presented with four options. Press 1 for New Messages, Press 2 for Starred Messages, Press 3 For Questions, Press 4 for Important information. Going to the new messages Mercy saw the welcome messages, the nurses had told her that this message would change every week. Mercy followed instructions to star the welcome message since it was the only message she had. The screen told her to press # to go to the beginning and from there she checked the important dates menu which told her how many days until her next visit and when her due date was.

This use case demonstrates how USSD can augment existing SMS based systems that support marginalized individuals living with HIV. By requiring a user name and password to access the USSD system mothers who share a phone with family members can call from any available phone. The application looks like a generic health tip service without proper credentials. We acknowledge that this system still has some security vulnerabilities since USSD communication is not encrypted - but is is an improvement on SMS only solutions.

5.2 Agriculture

Solomon is a Ghanaian farmer living in Gushie, 50km north of Tamale - the capital of the Northern Region. He and his brothers grow cassava, yams, kola nuts, and bananas for a regional farmers cooperative based in Tamale. The cooperative runs a marketplace to help match produce buyers and sellers. Every time Solomon goes to Tamale, he checks the records for how much his farm has sent to the cooperative, when the number doesn't match his expectations it can take awhile to sort out. The cooperative is also a great place to exchange information with farmers from villages Solomon doesn't visit often. There is a bulletin boards with fliers from the Ministry of Agriculture and NGO's advertising new, and sometimes old, techniques or tools. Solomon doesn't always trust this information and likes to ask what theories his friends have about it before he goes home.

This time when Solomon visited the cooperative they advertised a special star code to call and access information that would be useful to him. He had received SMSs from the cooperative before containing information about when crops would be collected or that the road into Tamale was bad. He also knew there was a way to post crops to the cooperative exchange via SMS. However, he personally didn't know any farmers who had used it and he heard rumors that it didn't always work if you typed information incorrectly.

The next week Solomon received another SMS reminding him about the star code and he decided to call it. The home screen was a menu with the following choices: 1. Weather, 2. Personal Account 3. Exchange Market 4. Community 5. Tips. After sending back 5 the next screen had the title of 6 new tips. The last line told him that 0 would go back and 9 would go to the forward in the list. The first tip was about about using herbicide for weed management - something the cooperative was always pushing and Solomon never had the savings to get. Though he wished to someday to use herbicide. There was an option to give feedback on the tip, so he reported that it wasn't very helpful since it was information he already knew. Solomon pressed 0 to go back and then went to the community forum. This was a message board with six different categories for posts. Solomon went into the section for cassava and found a list of posts by other farmers. He found out that he could make his own post by entering '+' and the '@' symbol would reply to someone. The last thing Solomon did was check the market place where he found a series of menus to help post crops to the exchange and see what the current prices were.

5.3 Data Collection

Josephine is a manager working with the National Immunization Program (NIP) in Kigoma, a district capital in Tanzania on Lake Tanganyika. She needs to receive information on a regular basis from health facilities, including weekly reports on vaccine stocks, as well as immediate notifications of stock outs and refrigerator failures. She is excited about the introduction of a USSD based system for data collection from rural facilities, as she has found using USSD to send money to relatives on mPesa both useful and reliable.

As part of the introduction of the new system, Josephine is leading training sessions throughout the district. Health workers from the rural areas have been attending these sessions where the NIP confirms that the current database is current. They use a web based management system to add contact phone numbers for each facility. When a number assigned with a health facility dials the USSD short code they get a simple menu system: 1. Submit Weekly Report, 2. Stock Out, 3. Fridge Status, and 4. Report Histories. The weekly report is a series of questions collecting the stock of six key vaccines as well as case reports for ten diseases. Josephine likes the fact that if the system detects format errors it replies with hints asking for the data to be resubmitted.

When Josephine calls the USSD number, she gets a different menu system from the health facility version. This admin USSD interface allows her to enter and view data for any facility while on the road. She can also associate new phone numbers with a health facility and manage information on the refrigerators. This is useful when she visits health facilities, because sometimes the data recorded can be inaccurate and, even on her smartphone, she has found it impossible to access the web interface on poor data connections at rural facilities.

6. DISCUSSION AND FUTURE WORK

While we have identified several use cases for USSD that extend the capabilities of GSM universal applications, we acknowledge that USSD is only a piece of the broader ICT4D toolkit. Organizations must survey available options in the context of the requirements of their individual project. If primary audience for a service is non-literate, IVR may be the best solution. If a project needs only simple messaging and privacy is not a concern or if frequent data collection will be done, SMS is a feasible option. And when there are few primary users a custom device specific application may work. However, there are three situations where USSD enables services that otherwise could not be offered as universal GSM applications. (1) when sensitive text based information must be shared, (2) when data collection is infrequent and complex, (3) when complex user interactions must take place.

The feasibly of USSD for large scale applications such as mobile money and interacting with mobile carriers is well documented. The framework presented in this paper shows how USSD can also be used for smaller scale operations similar to IVR and SMS. This opens up a large new design spaces to explore. There is a need to do user studies to understand the limitation of PIN and username based systems, which although the easiest from a technical stand point may not be the most user friendly. Systems should be designed that push the boundaries of what text based USSD systems can do such as creating a digital marketplace or math tutor. The user experience for these systems should be better studied to understand how to scale communities and improve services.

The principal motivation for this work originated in discussions with the Kenyan Ministry of Health (MOH) around SMS applications for maternal health and HIV awareness. Concern was expressed about the safety and ethics of distributing medical information over SMS. USSD seemed to be a solution that offed more privacy, even on the least expensive phones, as well as improved user experience and expanded design space. We were pleasantly surprised to find already existing third party operators offer USSD services. We now are currently in the process of testing the feasibly and design of our maternal health USSD application and working with the MOH to establish guidelines around its use.

7. CONCLUSION

The recent emergence of third party USSD gateways has opened up the design space for M4D applications that can reach users on the most basic phones. Traditionally USSD has only been used for banking and cellular operations, but by examining the existing ICT4D literature we can identify how USSD will complement and extend current uses of SMS and IVR for data collection, messaging, information query, social networking and making complex transactions. We built a prototype USSD application using an new library that provides the basic building blocks for general USSD applications. We have identified when M4D projects should consider using USSD as a solution and our USSD library will well in creating innovative services aimed at marginalized users throughout the world.

8. ACKNOWLEDGMENTS

The authors would like to acknowledge NSF grant IIS-1111433 which funded part of the work. We also thank Aditya Vashistha for photos of USSD systems in India.

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