User Errors in SMS Based Reporting Systems

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ABSTRACT

This note presents data from two large-scale data reporting projects in Pakistan and Laos using SMS as a channel of data collection. These projects share several major features: (1) the use of health workers personal mobile phones for data reporting (2) support from the Ministry of Health (3) planned expansion to every health facility in the country or province and (4) low ICT penetration at the periphery of the health system. Both projects are currently at the stage of rolling out to additional health facilities. The purpose of this note is to help understand the challenges faced in the early stages of the deployment by reviewing the content and errors in submitted SMS messages.

Categories and Subject Descriptors

H.1.2 [User/Machine Systems]

General Terms

Human Factors, Design

Keywords

Health Information Systems, SMS, reporting, user errors.

1. INTRODUCTION

Addressing supply chain issues in national health systems requires more than knowing something is broken. We need to know how it is broken, what broke, when it broke and we need to know all this when it happens. Based on this, theory a perennial promise of ICTD has been the accurate and up to date collection of health systems data. However, when deploying data collection solutions there is often a paradox of access: those locations for which we know the least also have the lowest access to ICT. It cannot be assumed that the most rural health facilities will have connected computers or data enabled mobiles. One common solution is to provide each health facility with a standardized phone and custom data submission software preinstalled. This is an expensive solution that generates many challenges in administering the devices and does not easily scale. We have worked closely with two large-scale projects attempting to overcome this challenge using a more scalable approach: SMS messages sent from personally owned mobile phones. In almost all countries, the vast majority of workers in rural health have access to a basic mobile phones.

Although SMS is universally accessible, the simple unstructured nature of the channel presents several challenges when collecting the inherently structured data from a health system. In this note we study the categories of SMS syntax errors encountered during the early stages of deploying large-scale health system monitoring programmes supported by the Ministry of Health. The systems have a common architecture and technology - they both support submission of data from mobile phones through encoded SMS messages. Our interest in pursuing this work is to understand the format errors an SMS reporting system might encounter, the rationale behind these errors, and methods of avoiding errors. Our belief is that understanding common errors will provide a framework for identifying deeper challenges faced by the deployments.

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2. BACKGROUND

As the electronic telegraph established in the mid nineteenth century, the ability to communicate even a small amount of digital data over distances can be transformative. Many ICTD projects have addressed data collection in resource-constrained environments with different mechanisms introduced for communicating digital data. With the rapid expansion of mobile phone networks, the dominant approach is to utilize telephony in various ways. These can be characterized both by the device (Smart phone, feature phone, or basic phone) and the channel (data, voice, SMS) and there are a wide range of trade offs in terms of bandwidth, user experience and cost that vary from country to country and project to project.

One of the simplest schemes for communicating data is encoding the data using Short Message Service (SMS) messages. The advantage of SMS is that it is near universal, it is a standard protocol, and all mobile phones can be used. However, messages are limited to 160 characters per message, which limits the data that can be communicated, and typing messages on phones can be slow for novice users. Costs per SMS are highly variable based on country, carrier, and payment plan. SMS has been used in a variety of contexts in mHealth and examples projects include: medication reminders [5], health worker reminders [4], birth registration [3] and vaccine stock level reporting [2]. The projects described in this paper build on this extensive work in the SMS space.

The first projects to use SMS did everything manually on basic phones [5]. This made it easy to start projects with just several phones and mobile airtime; however, it was difficult to efficiently manage messages. Early on, two primary methods emerged to manage large-scale SMS projects. The first, such as FrontlineSMS[1], used custom desktop software to send messages through an attached GPRS modem. The second was to host a management website that interfaced with the telecommunication system through an SMS to HTTP gateway that allowed a server to communicate with the telecommunication infrastructure through a REST API. Connecting with third party SMS to HTTP gateways is relatively expensive and depending on regulations, difficult to set up. To quickly set up automated SMS systems many projects now use Android phones as the gateway between their custom server based SMS management system and a gateway to the telecommunication backend, such as SMSsync[2].

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[1] www.frontlinesms.com

[2] http://smssync.ushahidi.com/

3. DEPLOYMENTS

In this note we examine SMS format issues from two health data reporting projects that aim to scale to the national or provincial level. Both projects are highly integrated with the health system and local governments. SMS was selected as a data channel independently in both projects because of its low cost, universal access and ability to work even over weak rural networks.

3.1 Punjab Disease Surveillance System

The Punjab Disease Surveillance System (PDSS) is an information system for tracking patient visits at government hospitals and health centers. The objective of this system is to help decision makers analyze and visualize data on reported cases in real time and at fine grain level with data being reported daily from all health facilities. This was deployed by Punjab Information Technology Board (PITB), a government department working on technology interventions for other public departments. The project began in 2012 as a web based information portal set up at every hospital in collaboration with the Department of Health. PITB hired dedicated data entry personnel at these hospitals who entered data on laptops using a USB modem. Since these operators are separate from hospital staff there is no added reporting burden for hospital staff. However, it is impractical to hire separate data operators for basic health units (BHU), which reside far from urban centers and many fewer cases to report. BHUs are often on the front lines of new outbreaks and getting timely statistics is important to prevent the spread to larger cities.

Since, a major goal of PDSS was to reach the basic health unit (BHU) and rural health center (RHC) in addition to well-connected hospitals a different solution was needed for the smaller clinics than what worked in urban hospitals. At this point we began collaborating with PITB in the design of a reporting system that would (1) be immediately deployable in rural Punjab, (2) scale to the provincial level and (3) require minimal technology costs or upgrades. A survey of digital reporting tools indicated that options requiring mobile data access would require devices that health staff did not currently have and a voice based systems could not economically scale to thousands of reports per day. PITB determined that the only feasible data channel for BHUs and RHCs would be SMS. In this section we will discuss the design, implementation, and deployment of the SMS based PDSS.

In designing the PDSS SMS syntax, we looked for existing and proven SMS reporting examples. One such example is the SMS reporting wheel from InSTEDD[3]. This wheel encodes the date, disease and number of cases in a paper based job aid (Fig. 1). The data types are represented by three concentric cardboard circles. The circles rotate individually and have a two-digit code plus third checksum digit. Each data entry on the wheel has a corresponding three-digit code and the wheels can be aligned to form a nine-digit report. There were three major motivations for using the SMS wheel: (1) numbers are easier to enter on T9 keypad mobile phones, (2) the wheel simplifies translation from data entities to encoded numbers and (3) the checksum provides error detection for mistyped numbers.

Figure 1: Close up of the SMS reporting job aid for PDSS

Once the reports have been decoded, data is stored in a central server, which is accessible through a web dashboard and integrates with the provincial hospital reporting system. This dashboard is accessible by PITB, the Health Department and WHO officials. Currently it displays specific graphs to show the reporting performances of each district. PITB and WHO work together to export the data in excel format for analysis and produce weekly epidemiology situation report bulletin distributed to DOH officials.

3.2 Laos SMS Immunization Manager

The Laos SMS Immunization Manager (LSIM) is a collaboration with UNICEF and the Lao National Immunization Program (NIP)[1]. The motivation for the project was to build a system to collect data on the status of the vaccine cold chain to ensure that vaccine refrigerators remained in good working condition. It is important that vaccines are stored in a fixed temperature range (usually between 2°C and 8°C) so that the vaccine keeps their potency. In order to track cold chain issues temperature logging devices have been distributed to all health facilities. These devices (30 day temperature recorders or 30DTR) track the refrigerator temperature for thirty days, recording if the temperature has been too high, or too low for an extended period of time. Both of these types of alarm indicate that the refrigerator should be serviced in some manner. This project is intended to support data reporting from all health centers (966 sites) and all vaccine storage locations (166 sites including both district and provincial vaccine stores) on a monthly basis.

Based on the intended scale of the project the design team concluded that SMS would be the best mechanism for submitting data. Discussions with NIP led to a decision to collect both the temperature alarm data from refrigerators as well as the stock levels of selected vaccines. The syntax enables monthly vaccine stock reporting as well as real time updates to a refrigerator's working status. The continued evolution of the SMS syntax expanded the potential for errors during SMS reporting.

In February 2014 we released a prototype for an automated SMS reporting tool that was deployed in 35 pilot sites and would be rolled out in the next stage of the project. This system was developed on top of RapidSMS but used a custom message parser since the default parser in RapidSMS cannot handle multiple operation codes in a single message. To get messages from the Lao telecommunication network into RapidSMS we used an Android SMS to HTTP gateway. With this RapidSMS based prototype automatic replies are sent after every submission confirming a successful message or reporting any errors found. This two-way interaction with the system not only provides confirmation that messages are received but also gives rapid

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

feedback. This feedback helped to standardize the messages as some users self corrected messages based on the automated response. For example one user sent "SL0 P550D4250" which resulted in a parse error because the 0 should be in front of the SL (stock level) tag. Two minutes later the same user sent in the correct message "0SL P550D4250" based on the automatic error message.

4. ERRORS

It has been noted that SMS has a high potential for inaccurate reporting [6] and during each design phases a primary consideration was creating a SMS format that was both simple to submit and parse. Despite efforts in both projects to reduce sources of error the unstructured nature of SMS will inevitably result in syntax errors.

The reporting syntax developed by each project was very different and designed to fit the unique needs and constraints of the project. The official syntax for the Pakistan project (PDSS) was a comma-separated list of the nine digit codes for all case reports on that day. From March 2014 through September 2014 PDSS received 22,036 messages, however, only 7,743 (35.1%) of these messages were in the official comma separated format. Syntax complexity was minimized in the Laos (LSIM) design by choosing to ignore whitespace and separators. From July 2014 through December 2014 the LSIM system received 273 messages, however, 31 of these messages were spam. The 242 messages intended for the system came from 35 health facilities and 195 (80.6%) of these were correctly formatted.

There are four primary methods of reducing reporting errors that each project is pursuing: (1) modifying parsers so they can extract data even with trivial format issues, (2) provide real time automated feedback on the success of each submission, (3) providing a moderator interface for admins to manually fix messages, (4) improve training materials and job aids. In the rest of this section we will analyze the types of errors in each system with the goal of informing future design improvements in these four areas.

4.1 PDSS Syntax Errors

In PDSS, the original message format was very restrictive and expected a comma-separated list of 9 digit numbers from the job aid. Such a stringent requirement on structure of incoming messages explains why only 35.1% of messages were parsable. The first step we took to improve the message parser was to simply extract all non-contiguous nine digit strings from incoming messages. Doing this we successfully parsed 9,063 additional messages raising the success rate to 76.3%.

A second common formatting error was to enter the nine-digit number as three separate numbers corresponding to each field on the job aid. This formatting error is again trivial to search for and we modified the parser to extract groups of three digits separated by non-alphanumeric characters. This method found 5040 additional messages. Fig. 2 shows that how often different characters were used as separators for both three digit and nine digit submissions and although spaces and comma's are the most frequent a large number of reports use different characters. This ignores less frequent separators such as the following message that has three valid reports (bold) but many extra characters:

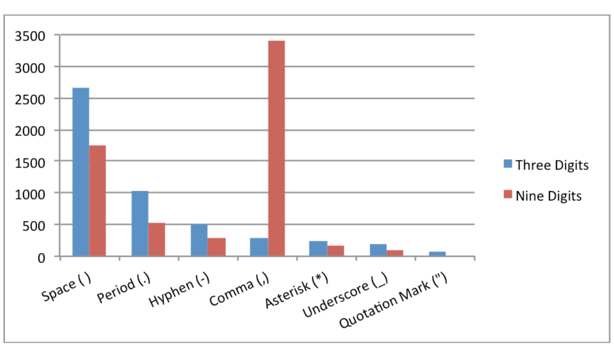

Figure 2: Separator Character Frequency in PDSS

Ari.>5y..,........,....,..,.,....Ari.<5y.,...,....,.,............Dia.<5y.**64659866 0**.Dia>**5y646598348**..........,..,.........puo.**646938660**.....,............

The content in this message demonstrates two important points about how people submit reports. First, they try to format the message to align on their personal mobile phone screen and since the new line button is difficult to find on T9 keyboards they will use punctuation to fill the gaps. Second, messages will contain extra textual data that attempts to explain the content for a human reader. This is very common with 2932 (12.8%) of messages containing more than 25% non-numeric characters. This is surprising given that extra characters make the message more complicated to type and more costly.

One source of confusion leading to the large number of reports with extra data is the fact that the World Health Organization (WHO) had been running the Disease Early Warning System (DEWS) in Punjab, which tracked case loads on a weekly basis via SMS. In DEWS SMS messages were received by district level officials who manually entered the data into online databases. Many of the BHUs submitting reports kept the DEWS format but added the extra nine digits from the wheel data. A typical example of this type of message is abbreviated in Fig. 3. The length of these messages indicates a substantial amount of effort on the part of health facility employees.

Day of the
month:12/05/14
Reported by: SMO
Facility Name:RHC
MALAKWAL
HF Code:146110
Dysentery <5

Figure 1: SMS in DEWS Format

All the previous variations in message syntax we have discussed have been intentional modifications on the part of the submitters. The final sets of syntax errors in PDSS are those that are unintentional mistakes. The most common form of this is the accidental introduction of a space. For example the following message should be five reports but the third and fourth (bold) have extra spaces that do not separate the message evenly.

550426660,550086237,**55 0231048**,**55 0086512**,550213048

Only 435 (1.9%) messages had a string of digits with length of seven, eight, ten or eleven. This low rate of unintentional syntax errors in encouraging and indicates that the SMS Wheel syntax is appropriate.

4.2 PDSS Reporting Errors

Even if messages are syntactically correct and the nine digit reports can be extracted from each message, there is still the potential for a mistyped digit. Because the SMS Wheel design included a checksum, a single digit error could always be detected. The 21,846 valid messages in our dataset contained 125,769 reports and of these only 2,867 (2.3%) could not be correctly interpreted. This means that one of the three triplets did not match to what was on the SMS Wheel, representing a correctly formatted but incorrect report. The rate of detectable single digit errors is extremely low and a good sign for the continued expansion of PDSS.

4.3 LSIM Reporting Errors

The message syntax in the Laos reporting evolved over time and thus was more complex than the simple number based syntax in PDSS. The LSIM syntax is based on two keywords FT for fridge tag and SL for stock level. Each keyword is followed by an operand signifying the number of alarms or various vaccine stock levels. This syntax replicates a very simple context free grammar and we use a basic top-down parser to process it. For example, the message FT A01 SL P30D20 would be used to indicate that fridge A has 0 high and 1 low alarms while the health center has stock of 30 vaccines for PCV (P) and 20 for Penta (D). This syntax obviously has much more potential for the introduction of errors, however, as indicated above of 242 messages since August 47 (19.4%) had errors. Further analysis of these error messages showed that 18 of the 47 error messages were repeated erroneous submissions and that 9 out the 47 messages were actually fixed by a later submission from the same phone number. Of the 38 incorrect messages that were not fixed by submitters, only one was not easily fixed by the project coordinator. Overall these error rates show that SMS reporting in Laos is a viable option.

We categorized the error messages into six different types, which are shown in Figure 4 and Table 1. The most common error was a missing keyword. The next most common error was submitting OK instead of 00 when there were no high or low alarms, this is easily explained by the fact that the fridge tags show OK if there have been no alarms. Another common source of errors was entering characters that are easily confused with Latin characters. We found that ð was used instead of d and O was used instead of 0. The frequency of these errors was rather small when compared to the total number of messages sent but they demonstrate an important challenge faced by the project. The Lao language has its own script and basics phones have limited support for this script. The project therefor used Latin characters which many people had limited familiarity with.

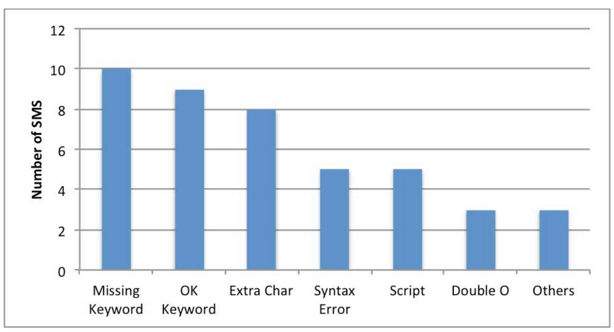

Figure 3: Frequency of Error Types in LSIM

Table 1. Examples messages for each type of error

Graphics	Top
Missing Keyword	B0p3250d3750 (no sl)
OK Keyword	OKSLP4972D9500
Extra Character	0D33pcv27
Syntax Error	P650,d3900-ok
Script	0p44ð43
Double O	OO P10 D5

5. CONCLUSIONS

Initially both of these projects faced questions about the feasibility of using SMS for data reporting. One of the concerns was the error rate of messages and the requirements for moderation of messages. Overall the error rates are sufficiently low that they can be managed as the projects scale through additionally use of automated notifying users of an incorrect submission and allowing them to learn the correct syntax by interacting with the system.

There were a number of types of errors that occurred. One problem was out of band information such as the name of the health facility or the sender. This related to the problem of associating phones with health facilities and receiving messages from unregistered phones. There was a range of punctuation and spacing in messages, which gave some errors for the PDSS project, while the LSIM project designed a format that was robust to spacing and punctuation.

We attribute some of the errors in LSIM messages to irregularities in message design. There were some changes made to the syntax to shorten common messages, which complicated overall design. The PDSS projected also demonstrated a training challenge, where users were confused between the format of the current project and an earlier reporting format.

Both projects have demonstrated a base level of feasibility indicating that SMS can be used as an appropriate channel for data submission. As the projects continue to scale we imagine that each system will have to find solutions to moderating and fixing the low level of inevitable errors, however, continued use of these SMS systems will make health systems data available much sooner from some of the most remote areas of Pakistan and Laos.

6. ACKNOWLEDGMENTS

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