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Integrating mobile and web health infrastructures in low resource contexts

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Abstract

Trustworthy and accessible health information is a key success factor for health management at all levels of the health system in any country. There is a rapid growth in mobile penetration in Less-developed countries (LDC). This has lead to many projects that want to exploit this new infrastructure to collect health data from remote and rural areas in LDC.

This thesis addresses the dynamics of integrating mobile Short Message Service (SMS) infrastructures and web infrastructures in low resource contexts. The method chosen in this project is Action Design Research (ADR). Information infrastructure theory was utilized by strategies such as bootstrapping and cultivation of the existing installed base. These strategies were chosen to make the project sustainable. The project focuses on the use of existing mobile infrastructures, including private low-end phones of health workers, to collect health information in LDC. This ADR project consists of four phases, which includes two field trips to Uganda and Rwanda. Accordingly, background studies and analyzes of relevant installed bases in both countries have also been conducted. This ADR project has resulted in the development of a software artifact used to integrate the web-based system the District Health Information Software 2 (DHIS2) with the SMS infrastructure. This artifact has enabled remote data collection using SMS messages in the DHIS2. During this ADR project, we observed different kinds of dynamics when integrating the web and mobile infrastructures. We observed differences in flexibility in these two infrastructures. We also found that political and organizational processes increased the complexity involved in the process of integrating the two infrastructures.

Further, we observed that some users have experienced difficulties using SMS messaging for remote data collection in rural Uganda. Most importantly, we found that creation of a generative software artifact stimulates innovation. We also looked at how the process of integrating the two infrastructures can be interpreted in the terms of digital convergence.

Overall, this project has shown that it is possible to extend the boundaries of the web-based infrastructures by the integration with low resource mobile infrastructures. Hopefully, this project will contribute to the collection of more accurate health data from both remote and rural areas in low resource contexts.

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Abbreviations

ADR Action Design Research

ANC Antenatal Care

ART Anti Retroviral Therapy

BIE building, intervention and evaluation

CDC US Centre for Disease Control

CHW Community health worker

DBS dried-blood spot

DHIS2 District Health Information Software 2

DNS Dynamic Name System

FIFO First in first out

GPRS General Packet Radio Service

HC Health Center

HIS Health Information System

HISP Health Information System Programme

HMIS Health Management Information System

HTTP Hypertext Transfer Protocol

ICT Information and communications technology

IDSR Integrated Disease Surveillance and Response

IM Instant message

IS Information Systems

IT Information technology

IVR Interactive Voice Response

LDC Less-developed countries

MEEPP Monitoring and Evaluation of the Emergency Plan Progress

META Medicines Transparency Alliance

MOH Ministry of Health

MSH Managment Sciences for Health

MSU Marie Stopes Uganda

MTN Mobile Telephone Networks

NGO Non-governmental organization

PEPFAR U.S. President's Emergency Plan for AIDS Relief

PMTCT Prevention of Mother-To-Child Transmission of HIV

PT Proficiency Testing

SMGL Saving Mothers, Giving Life

SMPP Short Message Peer-to-Peer

SMS Short Message Service

UK United Kingdom

USAID United States Agency for International Development

UVI Uganda Virus Research Institute

VHT Village Health Team

WHO World Health Organization

XML Extensible Markup Language

Chapter 1

Introduction

One recent and interesting change in the infrastructure in African countries, as well as in LDC elsewhere, is the rapid growth in mobile penetration. A director of GSMA[1] reported that mobile penetration in Africa reached an impressive 649 million subscribers in the forth quarter of 2011. This equals a penetration rate of 65 % [1]. If you add the fact that multiple people are using one subscription in a household or small village, then lots of people have access to mobile phones in Africa. It is noteworthy that very few phones in Africa are connected through landlines. Further, the African population is rapidly adapting to this new mobile technology. Of special interest is the use of mobile phone services such as mobile banking and pre-paid electricity. The applications people use are also part of the installed base [30] in a country. With the perspective of this growing mobile infrastructure in mind, there are numerous ongoing as well as finished mHelath projects using plain-text SMS for remote data collection and automated reminders in LDC [20] [28] [36] [18] [27].

This thesis is part of the Health Information System Programme (HISP) and is a collaborative network with a mission to improve health in LDC [5]. At the core of this programme is the DHIS2, which is a Health Management Information System (HMIS) used in more than 30 countries in Africa, Asia, and Latin America [3]. Trustworthy health information is a key success factor for health management at all levels of the health system in any country. However, not all countries have access to health information of acceptable quality. This is especially evident in LDC. The importance of good health information is underscored in an article [16] by AbouZahr with the following conclusion: "It is not because countries are poor that they cannot afford good health information; it is because they are poor that they cannot afford to be without it." [16].

This thesis will cover the implementation of support for remote data collection using plain-text SMS in the DHIS2. The DHIS2 supports the process of gathering and analyzing health data. The DHIS2 already have a standalone Java ME application using both General Packet Radio Service (GPRS) and SMS based data transport, as well as support for mobile browsers. In Uganda standalone software has been unsuccessfully

[1] An association representing the interests of mobile operators worldwide

integrated with the DHIS2 for enabling plain-text SMS reporting using a third part software for handling the SMS messages [22]. We define "SMS infrastructure" as a sub class of mobile infrastructure. The SMS infrastructure consists of actors such as mobile operators, SMS messaging service providers, mobile networks and mobile phones capable of sending SMS messages.

Sanner et al. [46] argue for a mHealth reference topology including following technologies: Interactive Voice Response (IVR), Plain-text SMS, Application (with GPRS and SMS based transport) and browser based solutions. As pointed out by Sanner et al., there are many advantages of using plain-text SMS for remote data collection in low resource contexts. First, all handsets support SMS so you can push information to users without knowing what kind of handset he or she is using. Second, Sanner et al. proposes a high prevalence of SMS mastery in most contexts. Third, plain-text SMS is easy to use for simple low-interactivity use cases. Finally, the plain-text SMS does not require installing, updating and managing an application on the mobile phone.

Sanner et al. [46] conclude that "the heterogeneity of privately owned handsets and variability in network coverage and signal strength suggests that hybrid solutions, combining multiple solution types, may be required in order to scale in many low-resource contexts ". We find this conclusion together with the above mentioned success stories of SMS in Health Information Systems (HISs) to be a strong arguments for adding plain-text SMS as a new way of reporting data in the DHIS2. Additionally, we noted a interest for plain-text SMS solutions from the DHIS2 community members in Uganda, Rwanda, Tanzania, Nigeria and Liberia and others. Plain-text SMS support will provide a richer variety of choices when setting up the DHIS2 to work with mobile phones.

One of the main differences between implementation of a HIS in the LDC and the developed countries is the available installed base. The installed base in this context refers to the existing infrastructure in the country. Both hardware and software are parts of this infrastructure. Information infrastructure theory proposes that we never have a so called "clean slate" situation where we can design software artifacts without considering the existing infrastructure. Thus, Hanseth proposes to use the term cultivate rather than design of infrastructure [30]. We also want to investigate how integration of mobile infrastructures can be related to digital convergence [50] [49] [33]. Installed base theory and digital convergence will be presented more thoroughly in the literature review in chapter 2.

When developing a solution for the DHIS2 we want the development of new functionality to benefit the users of the software artifact. Thus, the implementation must be general enough, so that it can be used in different context. We use Zittrain's definition [53] of generative artifacts as a guide to achieve generativity.

This project is part of the HISP network of action. The software artifact has been developed in close contact with the community. During the different stages of this project we collaborated with the Ministry of Health

(MOH) in Rwanda and Nigeria as well as Non-governmental organizations (NGOs) in Uganda. The DHIS2 is part of the health infrastructure in these three countries. The ADR [47] method was chosen due to the HISP network's focus on the development and implementation of a software artifact through participative design. Cooperation with actors from different countries will lead to a solution which is generative enough to be implemented in new contexts without large modifications.

1.1 Research Question

Information infrastructure theories are in many cases used to investigate the creation and evolution of an infrastructure in retrospect [15] [30] [31] [32]. However, in the present project I would like to actively utilize strategies found in information infrastructure theories as guidance when integrating the mobile and web infrastructures. The ADR method was chosen in order to find out whether or not these strategies are beneficial when integrating the infrastructures in the low resource context. The present project represent an explorative study into the dynamics involved when integrating the two infrastructures. The purpose of this study is twofold:

1. What kind of dynamics do we encounter when information theories such as installed base cultivation and bootstrapping are utilized as strategies for the integration of mobile and web health infrastructures in low resource contexts?
2. How can concepts like digital convergence and generativity together with information infrastructure theory be used as lenses to improve our understanding of the process involved when mobile and web health infrastructures are integrated in low resource contexts?

1.2 Organization of chapters

The rest of this thesis is organized as follows. The next two chapters will provide additional theory and background for this project. This project use ADR method that will be presented in the fourth chapter. The fifth chapter will describe the project which includes the field trips to Rwanda and Uganda. Finally, the two last chapters will provide a discussion of the observations and conclusive remarks for the present thesis.

Chapter 2

Literature Review

In this chapter I will present theories and literature relevant for the present thesis. First, I will give a short introduction to relevant aspects of information infrastructure theory. I will then present how generative software artifacts can be identified. Definitions of integration and interoperability will also be offered together with a presentation of some challenges that might occur when integrating software artifacts across organizational borders. I will also present the Network of Action theory. Finally, a definition of digital convergence will be provided.

2.1 Installed Base: Software as infrastructure

For most people software artifacts is not the first thing that comes to mind when they think about infrastructure. Most people will probably think of roads and railways, cables for electricity and so forth. However, Internet is also such a resource. A transparent and open architecture enables actors in the network to interact with each other on equal terms. It is easy to think of the Internet as an infrastructure, because it is always there in the background enabling other services to operate and "run" on top of it [48]. Dynamic Name System (DNS) is one example of a service that is implemented at the application layer of the Internet protocol architecture. DNS is used to look up network addresses by domain names and this service is identified as an infrastructure. The resource is shared with everyone, free of charge, completely open and transparent. From a technical point of view, DNS relays on services from the other layers below in the Internet architecture stack and would get this from the Transport layer, which again relays on the Internet layer and so forth. Every layer acts as an infrastructure for the layer above. Further, when a DNS serve both human and non-human actors it becomes an infrastructure for these actors. This view is shared by Star and Ruhleder [48] proposing that we should not ask the question of "what is infrastructure", but rather ask "when" something is an infrastructure and to whom. Hanseth [30] views integrated applications sharing data as infrastructure. Thus, the applications and services becomes infrastructure when they are serving as data sources for other applications.

HIS and more general enterprise resource planning systems are also systems that share characteristics with infrastructures [43] [15]. The HIS software, such as the DHIS2, is a benefit to many stakeholders in a health system. The HIS can be part of the health workers daily routine without the workers awareness of what kind of software they are using. In our case, when Community health worker (CHW) are reporting to the DHIS2 by SMS messages, the CHW simply need to compose a correctly structured SMS and send it to the correct service number. Likewise, when CHW in Rwanda is using paper based tools for reporting on monthly activities, the data will be entered into the DHIS2 at the district level. The data may be pooled out of the system by other actors. These actors may be workers at higher levels in the health system or other computer systems. For these actors the HIS is clearly an information infrastructure.

Hanseth [30] suggests that when we look at software as an infrastructure, it will also affect the way we view software development. Viewing software as infrastructure changes traditional perspectives on software development. While traditional views focuses on development of singular software artifacts within a given time frame, the infrastructure perspective views the software as just one piece of a larger puzzle that both evolves and changes over time. Thus, the infrastructure is maintained and evolved when additional pieces like applications, information or functionality are added to the system. This system is what Hanseth [30] calls an installed base. Installed base is the available infrastructure in a given context and the environment in which we implement software. An installed base may involve both hardware, software, information and knowledge. If no actors, both human and non-human, know how to interact with the system, then the system is not part of any infrastructure.

Aanestad investigates the space between the novel future and durable presents in her article on innovation research [14]. She underscore the importance of not only how software artifact work by themselves, but also how they affect their environment. Aanestad suggest that the human ability to create complex systems may outrun our ability to govern them [14]. One software artifact by itself may seem harmless, but this will change when the software artifact is integrated into a web of ensembles [14]. Thus, the software artifact becomes dependent upon these systems and the artifact can no longer be removed or replaced without taking care of these dependencies. These complex ensembles start to spin out of control of the software designers and takes a life of its own. Consequently, the software artifacts becomes an actor in a network of actors. Hanseth [30] underscores this characteristics of the software artifacts by comparing the installed base with a living organism. This makes it more plausible to speak of cultivation of software artifacts inside the installed base, rather then looking at isolated software artifacts. Installed base theory view software artifacts as an infrastructure and the available infrastructure influences the design process when creating new software. Another aspect highlighted by Aanestad is the cost of software maintenance, accounting for somewhere between 65 to 90 percent [14] of the total lifetime cost for the software. As a result, the software artifacts cannot be viewed as singular isolated artifacts.

Viewing software artifacts as part of an infrastructure will change the way we think of software development and the methods to develop the software artifact. An argument for the importance of this change is the development of software in the context of LDC, in which the resources and infrastructure are sparse. Failures to adapt to the installed base and inclusion in a network of actors will ultimately lead to failure of the software artifact. The LDC are repeatedly subjects to short sighted projects, which can be labeled as pilot project, with little valuable contributions to the installed base. This is underscored by Lucas [37] who suggest that a majority of the Information and communications technology (ICT) application falls into the category of pilot projects. An overview white paper [36] points to 23 pilot projects which did not continue after the pilot stage in the years 2008 and 2009. In India, a larger country counted over 30 projects [36] in the same category. Even though a project may be financed by organizations outside the of a particular health system, it might be naive to think that the same project will not drain resources from the health system. Health works are often overburdened with obligations from such projects. This can lead to less motivated health works, which is a common problem currently seen as one of the most important health workforce challenges [29].

2.2 Generative software artifacts

Generativity is described by Zittrain [53] as one of the features of a technical artifact that drives innovation. For example, the operating systems like GNU/Linux and Microsoft Windows are generative systems. The architects of these systems did not have all possible future uses in mind when creating these systems. Instead, they provided a rich application programming interfaces allowing the users and software developers to access features provided by the operative systems to build third party applications. This openness for the creation of third party software is one of the properties that makes these systems generative. However, it is not the only property that define the generativity of a system. According to Zittrain's definition, generativity is the function of a technology's capacity for leverage across a range of tasks, adaptability to a range of different tasks, ease of mastery, and accessibility. These four characteristics can be interpreted in the following way.

The first characteristic of a generative artifact is leverage, which can be described as how the software artifact enable users to accomplish things that would be either impossible or not worth the effort without the software. Moreover, a generative technology makes a difficult task easier to accomplish. A second characteristic is adaptability, meaning that the software artifact should have a broad range of fields of applications. A software artifact used to solve many different kinds of tasks can be viewed as more adaptable compared to an artifact that only support a limited number of tasks. Third, the software artifact should be easy to use and master. The lower the competence needed to both use and master the

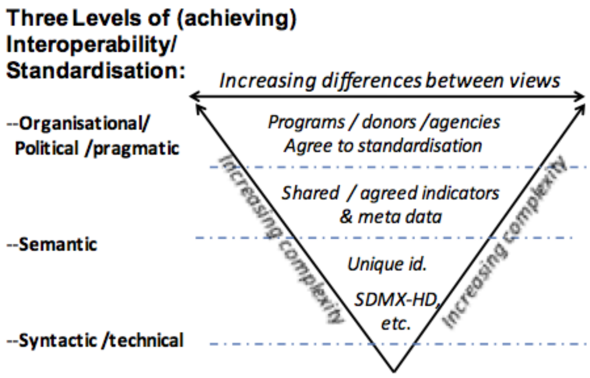


Figure 2.1: Integration / Interoperability [34] (adapted from Carlile [26])

technology to solve new tasks that is not part of the initial artifact design the more generative it is. A fourth characteristic of a generative artifact is accessibility. An accessible software artifact is both easy to acquire and use.

2.3 Integration and Interoperabillity

Braa and Sahay [34] distinguish between integration and interoperability. Integration is described as the process of joining distinct systems, which only means that there is some sharing of data between the systems without the use of standards. In contrast, interoperability is a term used when two or more systems exchange information by using shared and open standards. This shared standard makes the two systems reachable to another level of coexistence. Interoperability is therefore a more defined and precise term than the vague term integration.

The "Integration / Interoperability" model illustrated in Figure 2.1, describes the complexity involved in the process when the HIS make use of and exchanges information with other systems. The model is an adoption of a framework created by Carlile [26] for managing knowledge across institutional boarders. The model divides the problem of achieving interoperability into tree levels, and is visualized as a pyramid turned up side down. At the bottom we find the syntactic and technical level. This is the level regarding the functionality of the software used in the HIS. The next level is about the semantics in which the logic of the HIS is located. At this level we find indicator definitions, data definitions and so forth. At the top level, we have the organizational, political and pragmatic aspects. Here we find health management, programs, donors and agencies. The model consists of two axes. One axis represents the increase of complexity, while the other axis represent the increase in differences between views. The model displays the increasing complexity and differences in views from one level to another. According to this model, the technical level contains small differences in views with little complexity in the HIS. In the semantic level, shared data definitions and indicators lead to increasing complexity as well as differences in views. When the different stakeholders are to make an agreement to reach a standardized solution, the complexity and differences in views continue to increase even further.

Sahay et al. also emphasize the political dimensions involved in the process of integrating infrastructures. When two systems are integrated there might be a shift in the power balance between actors at the political level. Thus, the evolution of the installed base is also influenced by political actors [45].

2.4 Networks of Action

Network of Action theory [23] focus on achieving sustainability in action research projects through building of networks. Sustainability is defined as something that works over time and not within a limited time frame [23]. Actor network theory [23] is used to describe members of the network, including people, documents, knowledge, workshops, software artifacts and more [25]. The network of action theory acknowledge that the success of a HIS implementation relies on many factors. It is not only the quality of the code and distribution of the HIS that matters, but people, knowledge, as well as how the action adapts to the local environment are also important for successful implementation. Thus, sustainability is achieved by implementing the action within a network of actions rather than singular units (or as independents actions) [23]. The HISP network is such a network of actions [23]. Since its founding in the 1990s, one of the main concerns of the HISP network has been sustainability [25]. HISP aims to avoid short sighted pilot studies which often fail to reach critical mass of actors and scale beyond its initial settings.

2.5 Digital convergence

Recent research has increased the recognition and focus on installed base and digital convergence in IS research [50] [49] [33]. The biological term convergence is defined by the Oxford dictionary as the "tendency of unrelated animals and plants to evolve superficially similar characteristics under similar environmental conditions". One example is animals who develop a camouflage fitting its environment through natural selection. On the other hand, the term digital convergence refers to how digital devices and services evolves according to its environment. The term has lately often been used to describe how the introduction and widespread use of Internet have lead to an evolution of new services. These services combine traditionally separate domains and actors such as the ICT, Information technology (IT) and Entertainment Industries. The prime example of a converged product is the smart phone, which is a general purpose device that covers areas such as portable audio, video, video games, social networking, email reading, web browsing and so forth [49]. More specifically, the core of digital convergence is the merging of previously separate social-technical infrastructures and their installed bases [49] . In this thesis, digital convergence is defined in a more pragmatic way as a rather loose integration of services across different installed bases [33].

Chapter 3

Background

In this chapter I will present the background studies for this thesis. First, I will present a summary of the SMS for Life project. This is one of the most recognized and successful projects utilizing SMS messages and simple phones for remote data collection. Following this, I will introduce the DHIS2 including its data module. I will then give a short description of the RapidSMS framework. Finally, the background information for Rwanda and Uganda will be presented including relevant installed base and description of relevant aspects of the health system in each country.

3.1 SMS For Life

SMS For Life started as a pilot study in rural Tanzania. The objective of the SMS for Life pilot was to create and implement a HIS for gathering data on available stock information on anti-malaria medicine in health facilities in order to avoid stock-outs. The problem of stock-outs at the health facilities was described as a problem largely due to lack of efficient logistics. The situation could occur that the health facilities, which had run out of malaria medicine, had no knowledge about available medicine at the central pharmacy and visa versa. At the start of the SMS For Life study, there was stock-outs of at least one out of four types of malaria medicine in 78% of the health facilities. At the end of the 21-week long pilot study, the number of health facilities with stock-outs was reduced to 26% [20].

The work flow for the SMS for Life pilot study from an Information Systems (IS) point of view was as follows: First, a phone number for a health care worker was registered at each facility. This phone number was usually acquired during training sessions for the health workers. Once every week, a SMS message was sent to all the registered phone numbers asking for reports on the current stock of malaria medicine. The health care workers then manually counted the boxes of medicine stored at the facility. In the next step, the health care workers composed a SMS message, using their private phones. The composed SMS message contained an identifier for each type of malaria medicine followed by the available stock. The message was sent to a toll free service number. The SMS message was composed using the following structure [17]:

The letters indicate the type of malaria drug and the numbers indicate the available boxes of drugs.

The SMS for Life project is a private-public partnership initiated by Novatris, which is one of the largest producers of anti malaria medicine in the world. The IS and ICT solutions were developed by Vodafone, which is one of the largest telecommunications companies in the world. Additionally, IBM provided project management tools [20]. The companies joined the umbrella organization called the Roll Back Malaria Partnership in order to reduce the cooperate profile of the project [20]. The authors of the final report from the project states that the commercial model of the SMS for Life project is one of the reasons for the success. They also claim that the commercial model is more sustainable than a charitable model [38]. Thus, the project wants to take advantage of the economic motivation of the seller to make sure that all health facilities (the buyer) have available malaria medicine at all times. However, it is noteworthy that this effort is part of a program in which Novatris produces anti-malaria treatment medicine without earning profits. The company produced and distributed over 320 million doses of medicine from its start to 2010 [17]. In this case, the MOH in Tanzania and the commercial actor share a common interest.

Vodafone has created the HIS for data collection using SMS. However, this is not an open source project and neither the article, project report nor the project web page points or say anything about plans for making the platform available for others.

This raises an important question. Will a country who does not buy its anti malaria drugs from Novatris be able to get access to the SMS for life HIS? More importantly, will Novatris continue to support the system in Tanzania if the Tanzanian MOH choose another supplier of malaria medicine? If the answer is no, can a country allow this sort of lock-in to avoid stock-out? Additionally, what happens when partners for some reason looses interest in the project? I think that these dilemmas question the statement about sustainability in the commercial module where the supplier of the medicine also provides the HIS for distributing the medicine.

The project involved no centralized budget or formal contracts between the partners [38]. All of the partners covered their own expenses. If not stated otherwise, this leaves the copy right for the software artifact in the hands of Vodafone. This became a problem during the scale-up phase in Tanzania and with the start up of the project in Kenya and Ghana. In this phase, Vodafone shifted from being a partner to become a commercial provider of the software platform. When the project later wanted to add TB medicines to the report in Tanzania, the cost of getting Vodafone to implement the changes was too costly [39]. Because of the high cost of adding the functionality, two new companies were given the task to implement the SMS for Life implementation on their respective platforms. The companies competed for a contract. One of the two companies was awarded the contract and supplied the platform for pilot studies in Kenya and Ghana [39].

The project suggests 13 critical success factors for its implementation [38]. I would like to highlight some of these success factors: First, there should be mobile phone coverage at least 2-3 hours walk from the health facilities implementing the solution. Second, the service number for reporting should be toll free - as health workers may have phones with no credits. Third, the health workers should use their personal phone for reporting because the worker already knows how to operate and use the phone at daily basis. Fourth, there should be training sessions where the health worker learns how to report health information with their own phone. Fifth, the project has implemented phone credit payments as an incentive for timely reporting. Thus, a fixed amount of phone credit will be transfered to the users phone upon timely reporting. The credit can be used for private calls or messages. However, the success factor regarding the payments of phone credits has some problematic sides and must be carefully considered if implemented. Thus, an implementation should consider the goals of the health system as a whole and not just involve the goals of one individual program. For example, what happens when the health worker is overworked and/or lack motivation. Will health workers prioritize reporting data instead of other more relevant activities'? The sixth critical success factor is that the SMS for Life solution should be part of the governments official program portfolio.

The SMS for Life system is now in the process of scaling nation wide to 5 000 health facilities in 31 districts [36] in Tanzania. Pilot implementations will also start in Kenya, founded by Novatris, and in Ghana founded by Swiss TPH[1]. The SMS for life project had plans for a pilot in Congo to start in June 2012 [39]. However, this project came to a halt because of difficulties in finding the right partners. In 2012, SMS for Life had a pilot scheduled for starting in 2012. Cameroon actually skipped pilot phase and went straight to a country wide implementation [39]. The Cameroon implementation was not done at the time of writing. The SMS for Life project in Tanzania, and its following efforts in Kenya, Ghana, as well as the start-up in Congo and Cameron, shows that having health workers reporting data by SMS is considered to be successful. It has also given us valuable input for designing the structure of the SMS messages. Additionally, the success factors of the SMS for Life project is acknowledge to be a nice contribution to this field of study.

3.2 The DHIS2

The DHIS2 is a HMIS for collecting, analyzing, presenting and aggregating health data. The software is implemented in more than 30 LDC and is the national HMIS in 10 countries, including Rwanda and Uganda. The DHIS2 is designed for use at all levels of the health system, including health clinics, hospitals, health districts, NGOs, as well as at the national level. Data entered at one level in the health system are aggregated to the higher

[1] Swiss Tropical and Public Health Institute

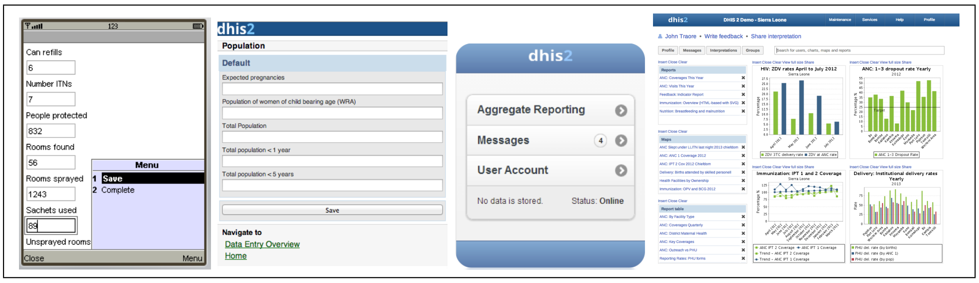


Figure 3.1: Screenshots of the DHIS2 from four different devices. From the left: 1) mobile java client 2) feature phone simple mobile web browser version 3) mobile web browser version for smart phones 4) computer web browser

levels. The DHIS2 can be used to enable stakeholders at all levels in the health system in order to analyze relevant data for evidence based decision making. Health facilities can also be allowed to access and analyze health data from other facilities, for example to compare their performance with other facilities.

The DHIS2 is designed with flexibility, generalizability and customization in mind. The DHIS2 can be implemented in different contexts and adjusted to local needs and do not require additional programming. The DHIS2 is an open source software and is licensed under the BSD[2] license. The DHIS2 can be run on a local computer or a central server.

The core technologies of the DHIS2 are based on Java and web standards[3]. The software is structured according to a model-view-controller design pattern. The DHIS2 is distributed freely on the project web page and can be run in a Java servlet container.

The DHIS2 can interact with a variety of clients. It can be accessed by a web browser on a computer or by using smart phones. Further, it can be also be accessed by using a Java client or a web browser on a feature phone. This is illustrated in Figure 3.1 showing screenshots from four different devices. In this project, we are expanding this list to also include simple phones without a web browser or Java support by interacting with the DHIS2 using SMS messages.

3.2.1 Data in the DHIS2

This project is about collecting and storing data in the DHIS2. A brief introduction to data module of the DHIS2 and how data is stored is therefore provided.

The data module of the DHIS2 consists of data elements, data sets, indicators and organization units. Data elements are grouped in data sets. Indicators are used for analyzing data and define formulas used for calculating proportion of data. All data in the DHIS2 is assigned to organizational units and all organizational units are organized in the

[2] Berkeley Software Distribution
[3] Spring Framework, Apache Struts, Hibernate, HTML and Javascript.

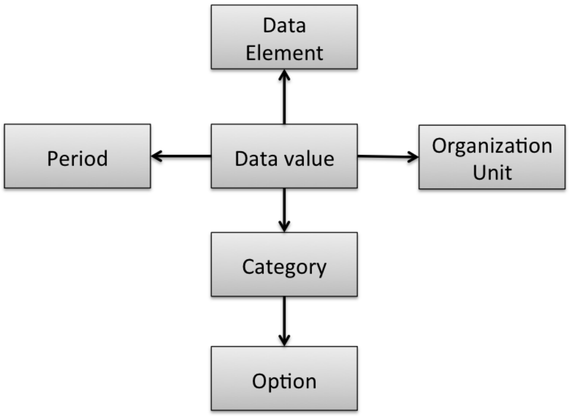


Figure 3.2: All dimensions of the data value stored in the DHIS2 database.

Data element	Period	Org unit	Category option	Value
Number of ...	22.04.2013 - 28.04.2013	Bo	Male	32
Number of ...	22.04.2013 - 28.04.2013	Bo	Female	16
Number of ...	29.04.2013 - 05.05.2013	Bo	Male	64
Number of ...	29.04.2013 - 05.05.2013	Bo	Female	42

Table 3.1: Illustrating data stored in the DHIS2

organizational unit tree. The organizational unit tree forms a basis for aggregation of data, in which data can be aggregated through the higher levels in the organizational unit tree.

All data values stored in the DHIS2 are linked to a data element, period, organization unit and a category option. These dimensions are illustrated in Figure 3.2. The period tells us the period in time the data was collected. For example, at which day, week or month in a given year the data was collected. The organizational unit tells us where the data was collected. The category options is the category of the data element and can for example be male or female. As illustrated in Table 3.1, data elements can be disaggregated into categories. This is the kind of data that we are going to collect by SMS messages in the present project.

3.3 RapidSMS

RapidSMS is an open source framework for collecting data using plain-text SMS message. RapidSMS is programmed in Python and Django and is a platform for building highly customized applications [**?**]. It has two main components. The first component is a back-end component responsible for receiving messages. The second component is a router service. This router first filter the messages, then a handler dispatches the message to an "RapidSMS app". The RapidSMS apps are responsible for parsing the message and storing the data. Examples of such applications are user registration, message log, uReport and mTrack.

GSM Modems and SMPP is supported through third party software, while HTTP forwarding is supported directly by the back-end.

In contrast to the DHIS2 where the customization is conducted without additional programming, the customization in RapidSMS is relying on programming new modules or RapidSMS apps. Although, some apps like user registration are included in the RapidSMS distribution, local development is needed in order to customize the software. There are local development of RapidSMS in both Rwanda and Uganda.

3.4 Rwanda

Rwanda is one of the smaller countries in Africa covering just above 26 square kilometers of mountain land. The capital Kigali, is located at an attitude of nearly a 1000 meters above sea level. The capital has an estimated one million inhabitants, while the country as a whole count more than 11 million people. Thus, Rwanda has the highest density in Africa. Administratively, Rwanda consists of five provinces that are subsequently split into districts, sectors, cells and at the lowest level villages. The village is the smallest administrative unit in Rwanda and there are approximately 15000 villages, meaning that each village has an average population of about 700 people.

Rwanda has good mobile coverage. The largest mobile operator being Mobile Telephone Networks (MTN), covers 95 % of the country. MTN is the operator that the MOH uses for mobile phones provided to CHW. Other operators in Rwanda are Bharti Airtel and Rwandatel with marginal market shares. It is noteworthy that Rwandans are familiar with SMS services. There is for example a system called Electrogaz, that enables people to buy credits for electricity by using SMS. There are also mobile banking services using USSD [4]. However, the most relevant SMS service, in light of our study, is the RapidSMS service used by CHW to report single cases of ANC and to alert the health center in case of emergency.

Our implementation is intended for use by the CHW throughout Rwanda. We are therefore going to take a closer look at how the CHW are reporting data today, what systems are in use and what kind of data do they report. The purpose of this investigation was to get a better understanding of the Rwandan installed base, in order to build on the existing infrastructure. This will increase the chance of success in implementing the software artifact.

3.4.1 The DHIS2 Installed base

Rwanda currently have five instances of the DHIS2, which are physically located in the server room at the MOH. One reason for running this many instances is different organizational unit structures of the stakeholders using the DHIS2. Another reason is the large quantities of data stored in each instance as well as access restrictions. This issue of interoperability

[4] Unstructured Supplementary Service Data

Figure 3.3: RapidSMS: Codes for reporting

between the instances is currently being addressed. However, in order to exchange data between the instances, all instances needs to have the same organizational unit structure. It is also noteworthy that there is no village level in the organizational unit structure used in any of the the DHIS2 instances in Rwanda.

HMIS

The national HIS instance of DHIS2 is accessible to all health centers and is used for monthly reporting from the health center. The monthly reports are provided by the responsible data manager at the health facility.

HealthFinance

This server is used to store data from the community based health insurance offices. It also store data from the Health Center (HC) which is reported by the CHW. This data is used to calculate the payments to the CHW Cooperatives on a quarterly basis.

Data warehouse / Dashboard

The data warehouse is a repository for selected indicators from HMIS, iHRIS[5] and Tracknet. It holds historical data that predates the HMIS instance of DHIS2. This is also the platform for the Dashboard, which is

[5]iHRIS Manage is a human resources management tool for the Health Workforce

the user interface for most program staff. In the dashboard they can select charts and report tables that they use frequently and create their own maps. The data warehouse is also used for a malaria surveillance system, as well as reporting system for child and infant death.

Bloodbank

This instance is used by blood collection centers. These centers are often churches and schools rather than health facilities. For that reason the bloodbank is not included in the HMIS.

3.4.2 Short description of other relevant systems

This section will give a brief introduction to systems in Rwanda, which is relevant to this thesis. None of these systems inter-operate with each other, thus creating islands of data. There is also examples where the users have to report the same data to different systems. One example of duplicate data entry is the reporting of Antenatal Care (ANC) data in RapidSMS, mUBUZUMA and the DHIS2.

RapidSMS

The RapidSMS solution in Rwanda was launched in 2009. ANC data is reported by the CHW using mobile phones and the data is stored in the RapidSMS database. RapidSMS is funded by UNICEF Rwanda, World Health Organization (WHO) Rwanda and United Nations Population Fund [7]. This project have been scaled up to cover the entire country [41]. The data is not shared with the national HIS (DHIS2), but is available at the the HC and at the District HC through the RapidSMS web interface.

The structure of the SMS message consist of a command followed by data values in a fixed order with each value separated by a whitespace. The message structure is presented in the instruction sheet in Figure 3.3.

Systems supported by Voxiva

Voxivia Inc is a contractor that have developed and implemented TrackNet and mUBUZUMA in Rwanda. The Voxiva solution supports both IVR and browser based reporting of data. IVR can be accessed by calling a toll free number. The Voxivia platform is proprietary software.

TrackNet

TRACnet is an mHealth system that has been supporting the national HIV/AIDS program of Rwanda since 2004. The project is funded and supported by the US Centre for Disease Control (CDC), which is the longest continuously operating national mHealth system in Africa. The TRACnet system is not only used for HIV/AIDS, but is also used to track Malaria, Tuberculosis and Other Epidemic diseases [42]. TrackNet is also used by practitioners to access test results from labs and to keep track of drug supplies for every health facility. The system is used by 400 users in different health facilities.

mUBUZUMA

Ubumzima translates to health, so mUBUZIMA simply means mHealth in the national language Kinyarwanda. The system is used for monthly reporting of performance based indicators for CHWs. The monthly report includes indicators for treatment of sick children, child nutrition, vaccination, maternal health, family planing, mortality, disease follow-up, drug and supplies.

3.4.3 Community Health Workers

The CHW plays an important role connecting the small communities in the villages to the health facilities. One of the most important tasks of the CHW is to refer patients to the health facilities. The CHW have both the means and knowledge to help the patients with information about available treatment, as well as communication with the hospitals. They also follow up patients, giving both physical care as well as social support, and make sure the patients are compliant to their treatment plan. The CHW may also distribute information and educate the community on health topics. [2]

Each Village has one CHW who is responsible for Maternal health and this CHW is always a woman. The other members of the CHW team are responsible for other activities, such as follow up of Anti Retroviral Therapy (ART) for HIV patients and other chronic deceases, distribution of bed nets etc. There are currently approximately 60 000 CHW in Rwanda. The CHWs are volunteers who are elected by the community which they serve. They are employed by cooperatives and not by the government or the health facilities.

Mobile handset

The MOH started to invest in phones for CHW in 2010. At date, every CHW in the entire country have been provided with a mobile handset [41]. These mobile phones are simple white label phones that have been branded by MTN. The mobile phone is without support for both Java ME and GPRS, so no browser capabilities are available. A picture of this mobile phone can be seen in Figure 3.4. It does however come with a color screen with a decent resolution, which is working well for creating plain-text SMS messages.

Reporting

One of the most important tasks of the CHW and the CHW team is reporting data monthly and per case. The CHW is located at the root of the health system as illustrated by Figure 3.5. The Figure 3.5 shows the flow of

Figure 3.4: Phone used by the CHW

data starting from the CHW and all the way up to the national level in the health system. We see that there are multiple databases that receive data from the CHW. While per case reports are reported by individual CHW, the monthly rapports are submitted by the group. There are mainly three systems involved: RapidSMS, DHIS2 and mUBUZIMA (also supported by Voxiva).

The CHW is responsible for reporting ANC to the RapidSMS database, as represented on the left in Figure 3.5. ANC data include; Pregnancies, Maternal Risk, Maternal Death, Birth, Child Health and Child Death. This data is reported using plain-text SMS. When sending a message to the RapidSMS system, the user will get a response message confirming that the message has been received by the system. ANC data are reported per case. Figure 3.3 shows the instruction sheet provided to the CHW for these tasks. All of these data elements are reported each time an incident occur. In case of complications, the CHW report this by adding a risk code to the SMS. Then an ambulance is dispatched from the nearest relevant health facility or hospital.

The next flow of data is the one for the national HIS with monthly reports. This data is usually reported on the same day the CHW reports to the mUBUZIMA system. This system is paper based up until the data reaches the Health Center. This means that the data is aggregated manually twice. First, from Village to Cell and then from Cell to Health Center. The aggregation at the Cell is done by a Cell coordinator. At the health center level this data is entered into two different instances of the DHIS2. One instance is named HMIS, which is the national HMIS. The second instance is the one used for Health Finance.

On the right side of Figure 3.5 we find the Voxivia systems that the CHWs are reporting to. The first system is TrackNet, which is responsible for reporting incidents of HIV and IDSR. The second system is mUBUZIMA, which is the system for monthly reporting of performance

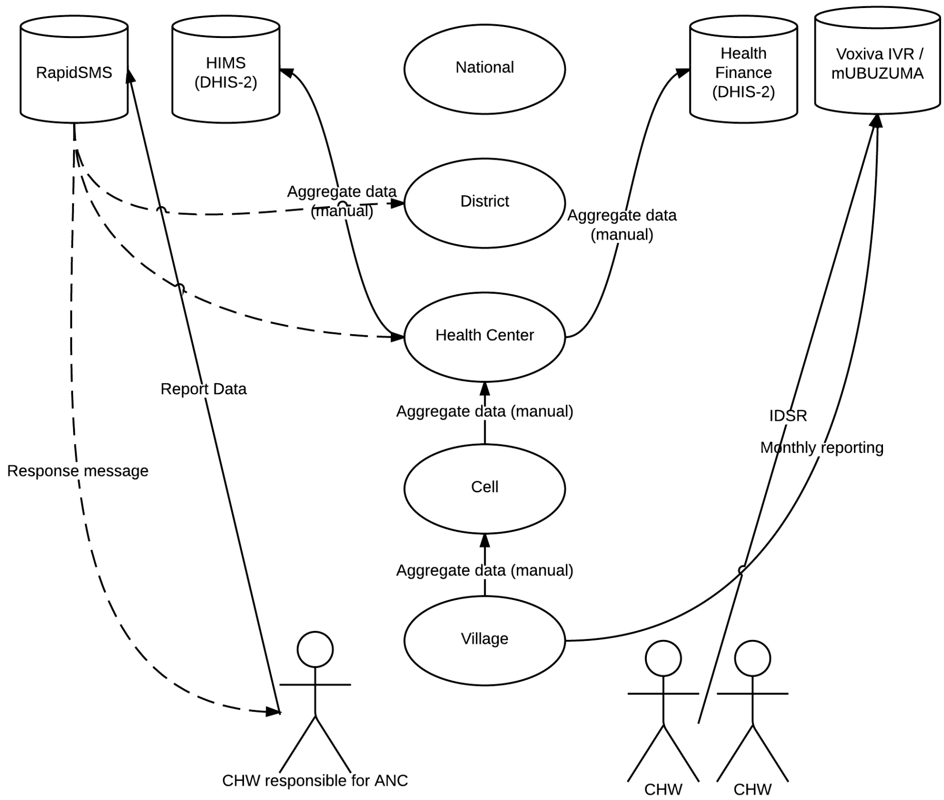


Figure 3.5: Data flow from the community to the national level in the Rwandan Health System

based indicators for community health workers. The monthly reporting is done by the CHWs as a group and not individually like Integrated Disease Surveillance and Response (IDSR).

Salary

The CHW are organized in cooperatives and the cooperative receive payments from the MOH. There is typically one cooperative in each district. This cooperative is connected to the District Hospital. The payments from the MOH to the cooperatives are based on a set of performance indicators from monthly reports. The tariffs for these indicators are set by the MOH and represent services provided by the CHW. For example, every "number of women accompanied/referred to HC for prenatal care within first 4 months of pregnancy" will generate $ 2.24 of income. [40]. On average, each CHW cooperative earns approximately $4,000 dollars per quarter [6]. The cooperative can choose how they divide and use the income. In 2010 there was approximately 60,000 CHW in Rwanda [35].

3.5 Uganda

Uganda is a country with great challenges in terms of providing health care. With a population of just above 33 million and a life expectancy at birth of 54 years [52], there are no promises of a long and profound life for the many children of Uganda.The country has an age structure that is totally off balance. 49 % [11] of its population is within the age range from 0 to 14 years old with a median age somewhere between 15 and 16 years [10] [11]. Some health issues are relevant in explaining this skewed distribution of age. One of the most obvious explanation is HIV. About 1 million people live with HIV and near 8 % of the population in the age range from 15 to 49 years are infected (UNAIDS).

In 2011 the antiretroviral therapy coverage in Uganda among people with advanced HIV infection was 54 % [10]. Further, the estimated percentage of pregnant women living with HIV receiving antiretrovirals for preventing mother-to-child transmission was 50 % in 2011 [10].

Another major concern and a burden for the Ugandan health system is the high maternal death rates. The inter-agency estimate for maternal mortality ratio (per 100 000 live births) is 310, ranking Uganda as the 36th worst country in the world to give birth [11]. The lifetime risk of maternal death in Uganda is 1 in 49. In comparison, the lifetime risk of maternal death in Norway is only 1 in 7900 [8].

3.5.1 Health System Structure

The structure of the Ugandan health system is as follows. At the ground level is the Village Health Team (VHT). The VHT is equivalent to a group of CHW, but they are never referred to as CHW in Uganda. Similar to the CHW in Rwanda, the VHTs in Uganda are also volunteers who are elected by the community they serve. As volunteers they do not get salaries. However, they do get some accessories that will help them to conduct their duties as VHT. Examples of accessories can for example be a bicycle, a pair of boots, a raincoat, a bag, a mobile phone, cloths or an umbrella. When interviewing a VHT leader, he underscored the importance of voluntarism by stressing that "the incentives are only there to enable them to do their work". The VHT team leader believed that if the VHT feel that they are payed, they will start to look at their duties as ordinary work and expect regular salaries.

The health facilities in Uganda have a high level of NGO interference. About half of the 5000 health facilities are run by NGOs, religious organizations or private for profit and non-profit initiatives (mTrackReport).

Above the VHT we find the HC II. The HC II should have the means to treat the most common deceases and a midwife to perform ANC. It is not a requirement for the HC II to employ a doctor. Cases that are to complicate for the HC II will be referred to HC III. HC III have larger staff than HC II but without doctors. However, there should be facilities like a lab and a maternity ward. The health center are also lead by a senior clinical officer. At the level above HC III is HC VI. This level should have a doctor in addition to the senior clinical officer and the ability to admit patients. At the level of HC VI is a surgery room for emergency operations [9]. Each district should have a district hospital. The main difference between a HC IV and a district hospital is specialist clinics. The health centers and hospitals can either be run by the government or by NGO. During the field trip I visited both a governmental run health center at level IV named Bukuuku HC and a privately run health center III named Mitandi HC.

3.5.2 Village Health Team

Depending on the different programs of the NGOs, the VHTs typically involves responsibilities like lecturing the village inhabitants on topics of sanitation, family planning, as well as to inform and refer pregnant women to ANC programs at the nearest health clinic and help organize immunization programs. Some VHT might even be trained to give immunization. In the SMGL district, the VHT also follow up the pregnant women in his or her village and make sure that they show up for their ANC visits. The HC may contact the VHT to find out why a woman is not showing up for her second ANC or third ANC visit. Each VHT should be responsible for 25 to 30 households according to team leader who referred to this practice as the official policy. The reason for the low number is because when the number of households exceeds this limit the VHT will perceive their VHT duties as work. However, when we talked to VHT and HC staff, they reported much higher numbers per VHT, the highest from 150 to 180 households for one VHT. The VHT can be viewed as the extended arm of the health facilities. The VHTs are organized by the NGOs. In the districts we visited the two NGOs that organize the VHT named Saving Mothers, Giving Life (SMGL) and STRIDES. There are also concerns about VHT members working for more than one NGO at the same time. The VHT also make some money on buying and selling transport vouchers. These vouchers are used for transport to ANC visits and when performing delivery. The vouches guarantees cheap transport for the mother to the HC. The VHT will organize the transport by using his or her mobile phone to call the driver and alert the HC or Hospital.

3.5.3 The DHIS2 Installed Base

There are three instances of the DHIS2 in Uganda. MOH, MEEPPE and META have the following setups:

MOH

The National HIS instance called HMIS1 is run by the Ugandan MOH. The system consists of one central server used by the whole country. Additionally, there is a test server used to be used for testing. All maintenance, upgrades and access are controlled and conducted by the MOH staff.

MEEPP

Monitoring and Evaluation of the Emergency Plan Progress (MEEPP) is a collaborative effort between United States Agency for International Development (USAID) and the U.S. President's Emergency Plan for AIDS Relief (PEPFAR). PEPFAR funds more then 80% [12] of HIV/AIDS activities in Ugand and the DHIS2 is used to collect data on HIV/AIDS. MEEPP has developed its own branch of the DHIS2, which includes a new module for narratives. They have both a production and a testing server. The development of the narrative module is conducted by an hired consultant.

META

Medicines Transparency Alliance (META) maintains a server for the MUJHU project. The MUJHU project involves tracking of HIV positive pregnant women by using the patient tracking module in the DHIS2. This model is currently under development. META also provides training in how to use the DHIS2 for the MOH.

3.5.4 mTrac

The mTrac project in Uganda is another project utilizing SMS for remote data collection. mTrac have gathered considerable momentum and is scaling up nation wide. This is one of the few projects that was approved to proceed after the Ugandan eHealth Moratorium in 2011 [22]. The project targets both tracking of medicine stocks and disease outbreaks for all of Ugandas 6000 health facilities and 8000 community based drug medicine-distributing village health workers (VHW) [13]. mTrack also have a module for an anonymous feedback channel, where the community members can send SMS messages with complaints concerning the health servicess. [36] Beside SMS, mTrack also utilizes USSD and web-based forms for data collection [36]. the mTrac project was piloted in 170 health facilities in the Gulu and Kabale districts in Uganda.

The project is run by the Ugandan MOH with support from Department for International Development in the UK and UNICEF Uganda. mTrack is built upon the RapidSMS platform provided by Unicef. RapidSMS is an open source framework for dynamic data collection using SMS[6]. The VHT as well as other health facility staff use their own private mobile phones for reporting by sending reports via SMS messages.

This project has transformed paper based HMIS forms into SMS forms. The weekly HMIS report can be sent by using SMS. An alert system is also in place where notifiable diseases or drug stock out are reported. The alert SMS will be sent to District Health Teams and appropriate HC.

The work flow from a system point of view is as follows. The registration of a user is done by sending a SMS message with the command "JOIN" to the service number. The system will then ask the user what

[6] http://www.rapidsms.org/

role the user has. The possible answers are "DHT", "HC" and "VHT". This question is followed by a question of which district the user belongs to. Upon completion of the registration process, the user enter a training mode where the user need to go through some training sessions filling out training forms before entering the production (live) system.

If a user move to another region or health facility (role), then the user needs to either change the name of the health facility they are assigned to or remove the user from the system by sending the command "QUIT" and then join again by sending the command "JOIN" to the same service number.

The mTrac uses two format for remote data collection. One format uses a key and value structure with a separator. The other format uses the position of a value in the text to identify the value.

The first format is a command followed by a key/code value structure. Figure 3.7 shows the sheet for reporting on diseases. This sheet is first filled with pen and paper before the SMS message is composed. A dot is used as a separator after the command "CASES" and after every code and value. Only none-zero values are reported in this form, so the SMS message for reporting data only consists of the elements inside the red squares in figure 3.7.The result is the SMS message "CASES. MA.34. SA.7. AB.2. CH.1".

The second format is without keys, it is the order in which the numbers are entered that links them to the data elements. As illustrated by Figure 3.8, the first data element is "Suspected malaria cases", which is positioned first in the composed SMS message. In this format, zero cases are also reported because the order of the numbers is significant. A dot is used as a separator after the command "test" and between every number. Composing an SMS from the manually filled out help sheet in figure 3.8 would look like: "TEST. 8. 0. 0. 8. 7. 3. 4". [4]

There are a total number of 6 mandatory and two optional weekly reports form, with a total of 67 data elements. This means that each health facility reports 6 SMS messages every week.

If the user reports late, then mTrac reports within the standard reporting period and the user need to send paper based reports to the district. If wrong data is sent to the system, reporting the same form again will overwrite and correct the data.

In addition to the aggregated weekly reports, the system is also able to handle notifiable diseases. This is not a format, but simply a message where the health worker writes a message like "We have three suspected cases of Acute Flacid Paralysis. Please send help." and sends it to the same service number as the reports. All data entered into the system is monitored by the District Health Teams which are responsible for view and approve all data collected in their respective districts [22].

One of the issues the Uganda MOH wanted to address with its eHealth Moratorium was the fragmentation of HIS caused by the over 100 mHealth projects implemented during the previous years up until 2011. The number of stakeholders and project is illustrated in Figure 3.6. In a letter issued by the MOH, all eHealth projects in Uganda are required to integrate with the DHIS2, which is chosen as the national HMIS in Uganda.

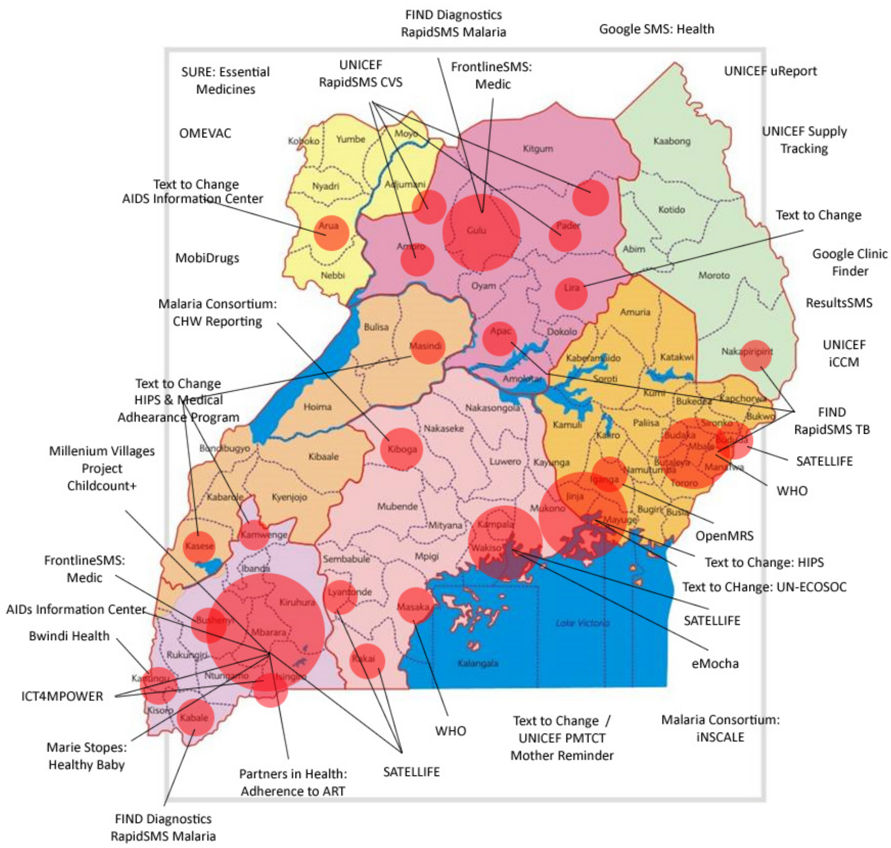
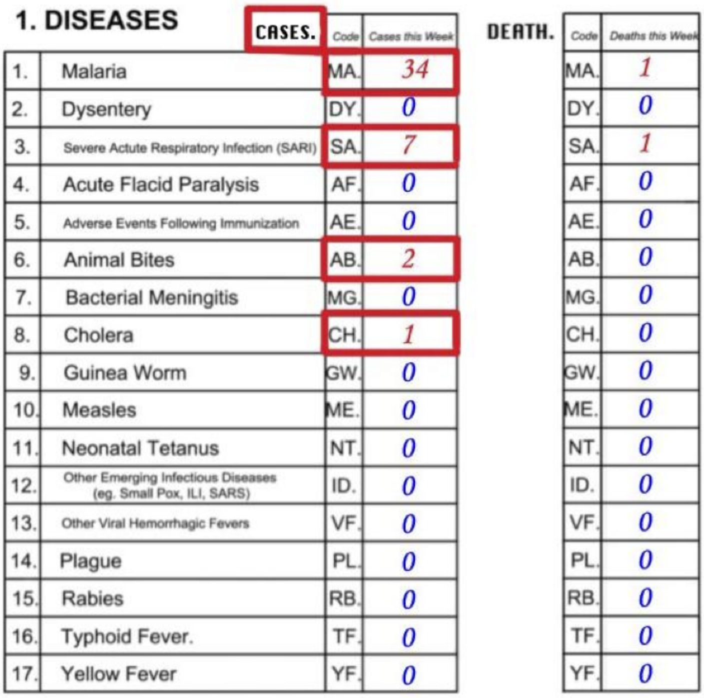


Figure 3.6: Map of mHealth pilots in Uganda [21]

The integration between mTrac and the DHIS2 is done by using a program written in Python that pushes data from mTrac to the national DHIS2 instance. Few problems were reported in regards of the actual implementation of the integration software. However, there were problems with keeping the health facility structure (organizational units in DHIS2 terms) synchronized. Without the same organizational unit structure it is impossible to transfer data between the two systems. This lead to the initiative for creating a national registry of health facility which can serve authoritative source for information on the organizational unit structure accessed by the DHIS2 instances, mTrack and other systems [22].



1. DISEASES

		CASES. Code	Cases this Week	DEATH. Code	Deaths this Week
1.	Malaria	MA.	34	MA.	1
2.	Dysentery	DY.	0	DY.	0
3.	Severe Acute Respiratory Infection (SARI)	SA.	7	SA.	1
4.	Acute Flacid Paralysis	AF.	0	AF.	0
5.	Adverse Events Following Immunization	AE.	0	AE.	0
6.	Animal Bites	AB.	2	AB.	0
7.	Bacterial Meningitis	MG.	0	MG.	0
8.	Cholera	CH.	1	CH.	0
9.	Guinea Worm	GW.	0	GW.	0
10.	Measles	ME.	0	ME.	0
11.	Neonatal Tetanus	NT.	0	NT.	0
12.	Other Emerging Infectious Diseases (eg. Small Pox, ILI, SARS)	ID.	0	ID.	0
13.	Other Viral Hemorrhagic Fevers	VF.	0	VF.	0
14.	Plague	PL.	0	PL.	0
15.	Rabies	RB.	0	RB.	0
16.	Typhoid Fever.	TF.	0	TF.	0
17.	Yellow Fever	YF.	0	YF.	0

Figure 3.7: mTrack format 1: Sheet to help composing SMS message resulting in the message "CASES. MA.34. SA.7. AB.2. CH.1" [4].

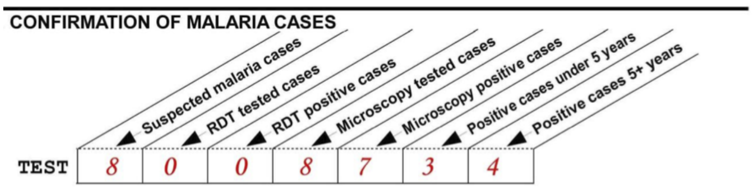


Figure 3.8: mTrack format 2: Sheet to help composing SMS message resulting in the message "TEST. 8. 0. 0. 8. 7. 3. 4" [4].

Chapter 4

Method

HISP is a Network of Action and the main research method used within this network is called Action Research. This thesis will therefore follow the Action Research discipline. However, in 2011, Sein et al. [47] wrote an influential article defined and outlined the Action Design Research (ADR) method. ADR is an Action Research method that is extended with software design and development in mind. Therefore, I chose to use the new ADR method for this project because this thesis focus on the development and implementation of a software artifact.

4.1 Introduction to Action Design Research

Action Design Research is a research method focusing on the process of gathering research results and knowledge, while at the same time solving practical problems. This is highlighted in the ADR principle of Practice-Inspired Research by viewing field problems as knowledge creation opportunities. ADR emphasize how ensembles, in our case software artifacts, are shaped by the organizational context during the development and usage of the artifact [47]. The focus on the organization distinguishes ADR from traditional Design Research. The latter pays more attention to the technical solution. ADR is explorative, so when embarking on an ADR journey, the research questions might not be as concrete as when conducting other kinds of research. One could probably say that there are similarities between ADR and agile development. Although the difference between them is that ADR is a research method and the agile development is a method for rapid software development through sparse documentation. However, both methods encourage the researcher/ software developer to have close contact with its research objects/ costumers. The ADR researcher should seek answers in the context of the practitioners and users rather then seeking answers in computer literature and by interviewing other technicians. However, some criticism warn the researcher using ADR method in ending up more as a consultant rather than a researcher. In addition, one can also question the objectivity of the researcher when he or she collaborates closely with the research object. However, the researcher should build the software artifact

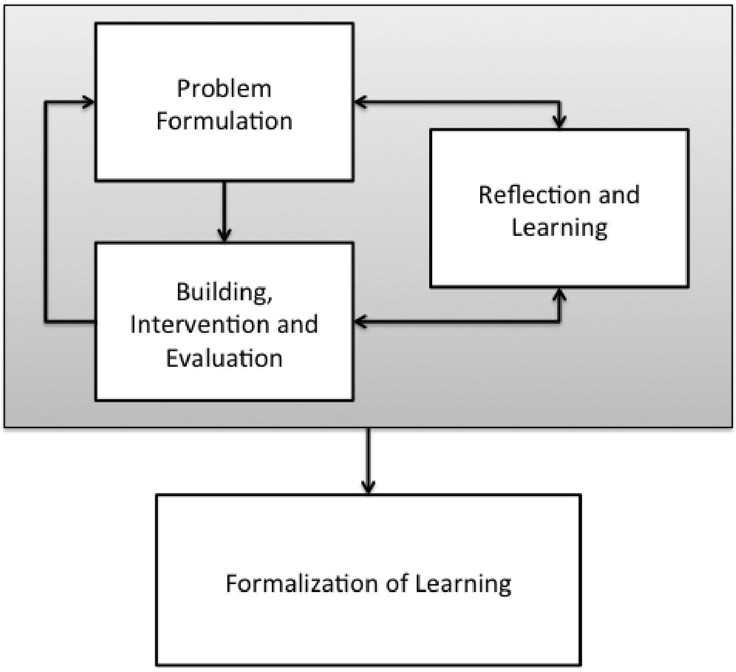


Figure 4.1: Stages in the ADR Method

based on theoretical background studies and conduct his or her research to achieve knowledge and not to “please the customer”. This is clarified by the ADR principle of Theory-Ingrained Artifact. This principle emphasize that artifacts created and evaluated by ADR method are informed by theories [47]. Moreover, it is important that the researcher acknowledge that conflicts of interest may occur between the research objective and business interests.

ADR is organized with the following structure. The first stage is called the problem formulation stage. When the problem formulation is defined in its initial form, then the next stage is the iterative process of building, intervention and evaluation (BIE). The BIE stage will start to build a software artifact. The building of the artifact is followed by the intervention in the organization, in which the artifact can be tested within the target organization by both practitioners and end-users. The final step of the BIE cycle is to evaluate the intervention by receiving feedback and conduct observations. Alongside the BIE and the problem formulation stage is the stage of reflection and learning. The reflection and learning stage is a continuous process which is present in all stages except the final stage of the method. This final step is called formalization of learning, and is covered by the conclusion in this thesis. The ADR structure is illustrated in Figure 4.1.

4.2 Project iterations

In ADR, the researcher will typically focus on one organization. In this study, the research will be conducted in multiple organizations and across country borders. There are however similarities between the installed bases in the neighboring countries Rwanda and Uganda. For example, both countries use the DHIS2 as their national HIS. Additionally, organizations in both countries share an interest in using plain-text SMS for remote data collection. By using the DHIS2, the organizations become actors in the HISP network. With this multi-site focus in mind, Titlestad et al. suggest that efficient design occurs when stakeholders, technical developers and domain experts meet in different contexts [51].

The following sections will focus on the BIE stages of this project. This is the part of the ADR method which is unique for every project. This stage also have the potential to change during the project. Only a short summary of each iteration will be provided without going into too many details.

4.2.1 IT-Dominant BIE

The BIE cycles in this project are based upon a IT-Dominant cycle in ADR [47]. The main reason is the fact that the initiative for the research was spawned by the DHIS-mobile research group. Additionally, this thesis have a stronger focus on the practitioners rather than the end-users. The end-users are included in the fourth and last phase. Figure 4.2 illustrates the four iterations of the project. The arrows indicate how each iteration starts by the researcher creating a software artifact. This software artifact is then intervened in the organization. Finally, the arrow points back to the researcher at the end of each stage, providing feedback to the researcher to be used for the evaluation phase. In the evaluation stage it is decided whether or not to initialize another BIE phase.

Phase 1: The prototype (Spring - Summer 2012)

The first phase started with the initiative to create a working prototype (as a DHIS2 module). The initiative came from the researchers in the DHIS-mobile team and the leader of the Global infrastructure group at the University of Oslo, also involving a preliminary project for SMS reporting in Nigeria. A prototype of the SMS module was developed and later showcased at a workshop in Mombasa in Kenya. Later in July 2012, the prototype was showcased at the Rwandan MOH. Rwandan MOH expressed their interest in the prototype and wanted to be involved in the development of the module. Evaluation of this phase included two observations: First, there was an interest in the HISP community for remote data collection using plain-text SMS. Second, we discovered bugs and other shortages which rendered the prototype useless outside the controlled demo environment.

	Phase 1	Phase 2	Phase 3	Phase 4
Researchers	Create first alpha version	Refinement of the alpha version	Refinement of the alpha version	Refinement of the alpha version and reach beta stage
Practitioners	Rwanda showcase	Demo in Rwanda (field study)	Demo in Uganda	
End-users				Pilot of the beta version

Figure 4.2: Table showing the different BIE phases of the project

Phase 2: Demo in Rwanda (13. August - 1. September 2012)

The second phase started with the refinement of the prototype into a more functional alpha version. There was also discussions about what kind of syntax the software artifact should support for the plain-text SMS messages. This phase also included a field trip to the capital of Rwanda, Kigali. The practitioners working at the MOH in Rwanda was included in the design process of the software artifacts and how it should be working.

The project in Rwanda came to an halt for unknown reasons. However, at the same time SMGL and CDC Uganda expressed their interest in this project. Therefore, the evaluation of this phase included the decision to initiate a new phase and set up a for a demo in Uganda.

Phase 3: Remote demo in Uganda (December 2012 - January 2013

In the third phase, the prototype was improved further based on the information collected in the previous phase and ongoing discussions within the team of researchers. A demo was set up for use in Uganda. The main method of communication with the practitioner was by using e-mail.

Phase 4: Implementation in Uganda (6. February - 7. March 2013)

Finally, in the fourth phase, the software artifact was implemented in Uganda. Training of VHT and MOH staff in plain-text SMS reporting. New requirements where discovered besides general fine tuning of the system.

4.3 Field work

Two field trips were part of this thesis. The first trip was to Rwanda where I worked together with the MOH in implementing the first plain-text SMS messaging system in the DHIS2. The trip lasted for three weeks, dating from 13. of August 2012. The second trip was to Uganda and lasted for one month, dating from the 6th of February 2013. While the first trip was focusing on working with the practitionars at the MOH, the second trip involved working with different NGOs and finally including the end-users in the study.

During the trip to Rwanda, I first held a training session for the people working at the MOH. Second, we had work-groups where we discussed how to implement the reporting forms they wanted to use for SMS-reports. Third, I conducted interviews of the MOH staff members. The trip also involved laying the ground work for setting up the server at the MOH in Rwanda to send and receive SMS messages. A lot of effort was also put into analyzing the organizational unit structure. This included adding new levels in the organizational hierarchy (sector and village). It also included adding users for the CHW with phone numbers.

During the trip to Uganda I held and participated in multiple training and demo sessions. We also had numerous meetings with different stakeholders and NGOs in the Uganda health system, including SMGL, CDC, USAID, Managment Sciences for Health (MSH), UNICEF and The MEEPP. Training sessions or demos were given to all of these NGOs. In addition, I went on a field trip to Fort Portal district where we visited two health centers, conducted training for the VHT, interviewed VHT and health workers at the facilities, as well as local data clerks responsible for reporting health data from the clinics.

Finally, we ended up with starting three projects within tree organizations in Uganda. The first project concerned data collection for a MEEPP project for Prevention of Mother-To-Child Transmission of HIV (PMTCT). The second project was about Mothers and Infant Mortality Weekly Aggregate Reporting for SMGL. The third project concerned Uganda Virus Research Institute HIV and CD4 Proficiency Testing Quarterly Report. The two last projects are both for the CDC. All projects will be described more thoroughly in the case chapter later in this Thesis. A collaboration with UNICEF for the SMGL and MEEPP projects was also initialized.

The starting of these three projects also resulted in the implementation of two new instances of the DHIS2. I also implemented new organizational unit structures and user accounts for these new instances during the stay in Uganda.

4.4 Data sources

Field Notes

Notes where taken during meetings, interviews, trainings and discussions.

Interviews

Semi structured interviews was conducted with VHT leaders, VHT and health works.

Voice Memos

Voice memos was used during interviews.

Observations

Observations was conducted during training of VHT leaders and VHT when using the system and sending SMS messages.

Mail and IM

A large part of the communication in the projects part of this thesis was conducted by Instant message (IM) or by e-mail. E-mails and IM messages are used as a data source in this thesis. All participants have been asked for permission to use the content of this communication as data for this thesis.

Various Documents

Investigating of the documentation from other systems like RapidSMS, mTrack and SMS for Life have proven a valuable source of information.

Chapter 5

Case

In this chapter I will present observations and discussions during the ADR project. First, I present three possible ways of integrating the DHIS2 and the SMS infrastructure. This is followed by a summary of each of the four BIE iterations in the ADR method. I will then provide a short presentation of the software artifact created during this project.

5.1 Possible solutions when integrating the DHIS2 and the SMS infrastructure

This section describes possible solutions for how to integrate the DHIS2 and the SMS infrastructure. The rest of this section will cover three possible ways to integrate these two infrastructures.

5.1.1 Separate applications: Interoperability

One possible way to integrate the DHIS2 and the SMS infrastructure is via another application functioning as an integration point between the two infrastructures. As illustrated by Figure 5.1, an external application X is operating between the DHIS2 and the SMS Infrastructure. This application X is handling the processing of SMS messages and interaction with the SMS users. All SMS communication is handled by the third system and later imported into the DHIS2. This is equal to the solution tested in Uganda where the data is received and processed by mTrack. Later, the data are supposed to be pushed to the DHIS2. The process of integrating these two systems is a complex task with many challenges. This complexity is underscored by the failure of integrating the two systems in Uganda. Examples of challenges which lead to a rise in complexity are:

- Synchronized Organizational unit structures
- Synchronized User base
- Synchronized Data Elements and Category Options
- Synchronized Data Sets

Another aspect with the external software approach is the fact that the DHIS2 and application X will have different support community and different user base. Networks of Action theory tells us that in order for a software project to succeed, there is a need for a strong interest in the project from multiple actors in a network. If the selected solution is either to create a HISP organized application X or to depend on an external third party application like RapidSMS, the integration point will need to have a large user base in order to succeed. If just one actor is depending on the software, the chance of success may be less than if multiple actors are depending on the same software.

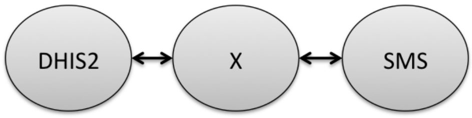


Figure 5.1: External application X interoperating with both the DHIS2 and SMS infrastructures

5.1.2 As a module inside the DHIS2

A second approach would be to create everything inside the DHIS2. An advantage with this solution is the direct access to the DHIS2 framework. Thus, organization units, data sets, data elements and category options are all available directly from the framework and there is no need for synchronization, integration and/or interoperability. Another advantage is the ability to configure the entire setup inside the DHIS2, which is a familiar environment for the user. A third advantage would be to reduce complexity in maintaining one system instead of two or even three systems.

5.1.3 Loose integration

A third approach would be to have a semi integrated solution where an application X, same as illustrated in Figure 5.1, is loosely integrated with the DHIS2. Application X is only responsible for sending and receiving SMS messages from the DHIS2, but the parsing of messages are done within the DHIS2. The application X would in many aspects be similar to a SMS Gateway or a SMS messaging service provider, hiding some of the complexity of sending messages in another application. However, the application could support queuing and scheduling of messages in addition to work as a router towards multiple SMS providers and mobile networks.

5.2 Phase 1: Prototype

In the first phase of the this case a prototype was created. This prototype was based on the background information gathered from different projects, such as mTrack and RapidSMS. In addition, there were a great deal of discussions within the HISP mobile group in Oslo about how to model the SMS prototype. Most of the participants in this process were HISP members of the research team in Oslo, consisting of two Master students, two PhD research fellows and one person with a Post Doc position. One of the PhD candidate worked on a SMS project in Nigeria. The project involved making a paper based monthly data summary form into an SMS form. This development was started by defining a SMS format. This was followed by a discussion about how the new module should fit into the DHIS2 architecture. Finally, a demo server was setup.

SMS format

The format and structure of the SMS messages were some of the first issues we discussed within the research team. One important design principal established early in the process was that the format should have the ability to adopt to the existing installed base in different contexts. Meaning that, we did not wanted to support just one format. In fact we needed a system that supported multiple formats. This is underscored by one of the researchers stating that:

> (...) We definitely need flexibility and to support a number of formats. (...)

Different countries have different installed base or technological heritage. This installed base may involve formats for sending structured SMS messages to interact with IS and in some cases even with existing HMIS:

> (...) I think we need to have some flexibility here, especially since we're coming in late in the game. We want to be able to replace existing solutions, or leverage already existing training and experience that's in some existing format. (...)

Another obvious factor in need for consideration was the limits of the SMS message. Although, most mobile phones will be able to put together a message consisting of multiple messages into one message. The maximum number of characters in a SMS message is 160 characters. That is, if the message does not include any special characters taking up more space. Adding a lot of formation and structure to the message will leave fewer bytes or characters left for the actual data that the user intends to send. One example illustrating this dilemma is the use of spaces to make the structured SMS messages more readable, and thus, easier to write:

> (...) I believe spaces would be good and make the forms more human readable. (...)

On the other hand, this would also have its disadvantages because each space would take up one of the 160 characters available in a the SMS message. One of the researchers pointed to this shortage:

> (...) having spaces means less number of data (...)

	Category 1	Category 2	Category 3
Data Element 1	A	B	C
Data Element 2	D	E	F

Table 5.1: Data element Category Option Codes

A format was drafted out to fit the monthly data summary form for the Nigeria case. The following format was suggested by one of the research fellows:

```
<codeword> A <value> B <value> C <value> D <value>
```

This format starts with a codeword that identifies the form. This codeword was followed by keys and values. The letters A,B,C,D represents the keys. All of the values in the example presented above were supposed to be numeric.

One of the following questions was whether the form elements should be predefined or auto generated. Additionally, how should we deal with the category, period and organizational unit dimension of the data values. One research fellow noted:

> (...) how do we deal with CategoryOptionCombo, Male/Female. (...)

Another research fellow responded:

> (...) We may need to deal with the categories as different elements (...)

The problem regarding how to resolve categories in the SMS format is illustrated in Table 5.1. One data element may have many categories. Categories can for example be gender or age. One proposed solution for this problem is to deal with each, which is also presented in Table 5.1. This solution identifies categories as different form elements in the SMS message. That is, code "A" may be the number of males who have received a certain treatment and "B" could be the number of women:

Another dimension for the data element is the period. The period for a data element is the time span for the data value. It was decided that the previous period would be selected automatically when receiving data in the prototype. Thus, if a user reports weekly data in week 52, then the period for that data will be week 51.

The organizational unit is the third dimension for a data element in the DHIS2. This is the organizational unit for the reported data. The research team decided to use the phone number entered in the user account as the link between the user and the organizational unit in the DHIS2. When the system receives a SMS message, it will search for the user based on the phone number and finally resolve the user's organizational unit.

The architecture

It was decided that the prototype of the SMS module should be developed as a module inside the DHIS2. Thus, the implementation should work out of the box. However, it should be possible to extend the current implementation for supporting features such as external queues of incoming and outgoing messages. Another requirement is that it should be possible to easily extend the implementation with new parses. A parser was implemented for supporting a format following the above mentioned specifications, but with statically defined codes as data element identifiers.

An in-memory First in first out (FIFO) queue was created to handle incoming SMS messages. The messages are stored in the data base for persistencey. Additionally, I did implement a ActiveMQ[1] based queue as a proof of concept. The ActiveMQ could potentially run on another server than the DHIS2 instance for load balancing. In addition, this queue could be a potential integration point. However, this was not included in the module due to the size of the ActiveMQ library, which would lead to a more than 10 % increase in size of the WAR file of the standard DHIS2 build. Core members of the development team considered this increase to be too much, because very few actors in the HISP network will have use for this model.

The first demo server

A demo server was setup for testing, development and demoing the implementation. The United Kingdom (UK) based SMS messaging service provider BulkSMS was a contractor for the SMS Gateway. This gave us a UK number. However, BulkSMS did not support Basic HTTP Authentication when sending messages to our server. We therefore setup a relay between the DHIS2 and BulkSMS servers in order to forward the messages with Basic HTTP Authentication.

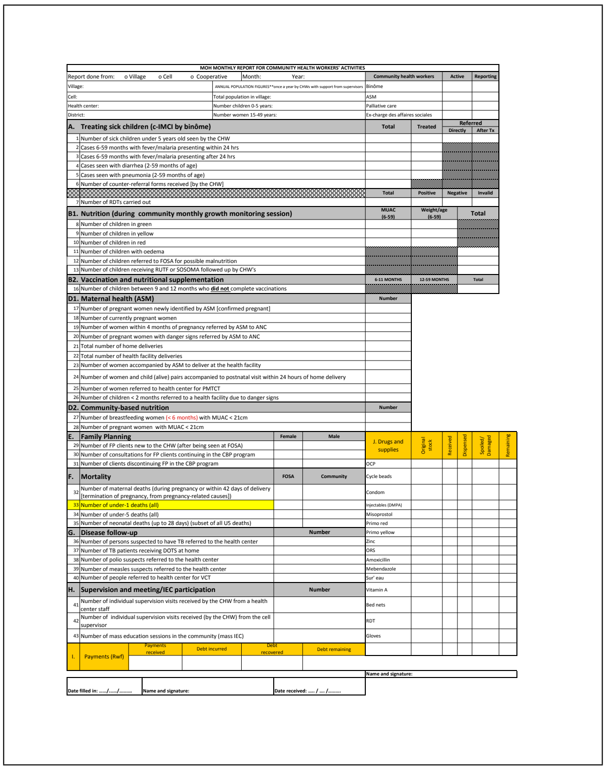
5.3 Phase 2: Demo in Rwanda

A DHIS2 mobile team member sent an email the 7th of June 2012, explaining that he wanted to showcase the prototype during the upcoming "DHIS 2 Academy East Africa 2012" workshop in Mombasa, which is the second largest city in Kenya, just 10 days later. After some intensive days we got the demo ready for the workshop with the positive response from from the team member in Mombasa; "This is actually working". This was the first time the SMS messaging system within the DHIS2 was setup in a low resource context.

The Rwandan Community Data Manager showed a particular interest in plain-text SMS for remote data collection in the DHIS2.

Coincidentally, my supervisor had already planned a trip to Kigali, in the period from 30th of June to the 7th of July 2012. In the following, I

[1]http://activemq.apache.org/



MOH MONTHLY REPORT FOR COMMUNITY HEALTH WORKERS' ACTIVITIES

Report done from: o Village o Cell o Cooperative | Month: Year:

		Community health workers	Active	Reporting
Village:	ANNUAL POPULATION FIGURES**once a year by CHWs with support from supervisors	Binôme		
Cell:	Total population in village:	ASM		
Health center:	Number children 0-5 years:	Palliative care		
District:	Number women 15-49 years:	Ex-charge des affaires sociales		

A.	Treating sick children (c-IMCI by binôme)	Total	Treated	Referred: Directly	Referred: After Tx
1	Number of sick children under 5 years old seen by the CHW				
2	Cases 6-59 months with fever/malaria presenting within 24 hrs				
3	Cases 6-59 months with fever/malaria presenting after 24 hrs				
4	Cases seen with diarrhea (2-59 months of age)				
5	Cases seen with pneumonia (2-59 months of age)				
6	Number of counter-referral forms received [by the CHW]				
		Total	Positive	Negative	Invalid
7	Number of RDTs carried out				

B1.	Nutrition (during community monthly growth monitoring session)	MUAC (6-59)	Weight/age (6-59)	Total
8	Number of children in green			
9	Number of children in yellow			
10	Number of children in red			
11	Number of children with oedema			
12	Number of children referred to FOSA for possible malnutrition			
13	Number of children receiving RUTF or SOSOMA followed up by CHW's			

B2.	Vaccination and nutritional supplementation	6-11 MONTHS	12-59 MONTHS	Total
16	Number of children between 9 and 12 months who **did not** complete vaccinations			

D1.	Maternal health (ASM)	Number
17	Number of pregnant women newly identified by ASM [confirmed pregnant]	
18	Number of currently pregnant women	
19	Number of women within 4 months of pregnancy referred by ASM to ANC	
20	Number of pregnant women with danger signs referred by ASM to ANC	
21	Total number of home deliveries	
22	Total number of health facility deliveries	
23	Number of women accompanied by ASM to deliver at the health facility	
24	Number of women and child (alive) pairs accompanied to postnatal visit within 24 hours of home delivery	
25	Number of women referred to health center for PMTCT	
26	Number of children < 2 months referred to a health facility due to danger signs	

D2.	Community-based nutrition	Number
27	Number of breastfeeding women (< 6 months) with MUAC < 21cm	
28	Number of pregnant women with MUAC < 21cm	

E.	Family Planning	Female	Male
29	Number of FP clients new to the CHW (after being seen at FOSA)		
30	Number of consultations for FP clients continuing in the CBP program		
31	Number of clients discontinuing FP in the CBP program		

F.	Mortality	FOSA	Community
32	Number of maternal deaths (during pregnancy or within 42 days of delivery [termination of pregnancy, from pregnancy-related causes])		
33	Number of under-1 deaths (all)		
34	Number of under-5 deaths (all)		
35	Number of neonatal deaths (up to 28 days) (subset of all U5 deaths)		

G.	Disease follow-up	Number
36	Number of persons suspected to have TB referred to the health center	
37	Number of TB patients receiving DOTS at home	
38	Number of polio suspects referred to the health center	
39	Number of measles suspects referred to the health center	
40	Number of people referred to health center for VCT	

H.	Supervision and meeting/IEC participation	Number
41	Number of individual supervision visits received by the CHW from a health center staff	
42	Number of individual supervision visits received (by the CHW) from the cell supervisor	
43	Number of mass education sessions in the community (mass IEC)	

I.	Payments (Rwf)	Payments received	Debt incurred	Debt recovered	Debt remaining

J. Drugs and supplies	Original stock	Received	Dispensed	Spoiled/ Damaged	Remaining
OCP					
Cycle beads					
Condom					
Injectables (DMPA)					
Misoprostol					
Primo red					
Primo yellow					
Zinc					
ORS					
Amoxicillin					
Mebendazole					
Sur' eau					
Vitamin A					
Bed nets					
RDT					
Gloves					

Name and signature:

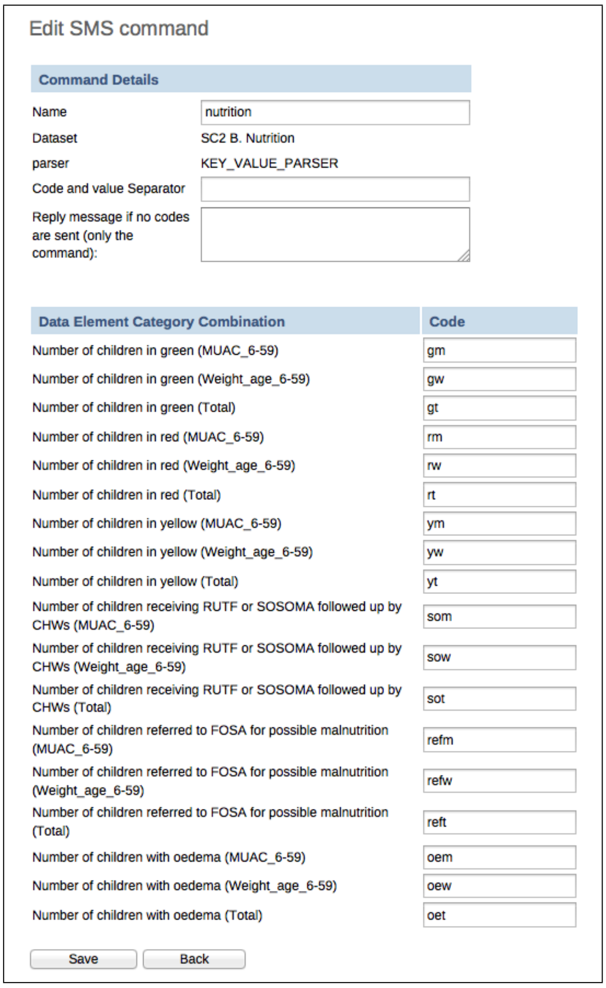
Date filled in: ....../....../.......... | Name and signature: | Date received: ..... / .... /..........

Figure 5.2: MOH monthly report for community health workers activities. Most noteworthy, this is a complex paper form with 59 data elements and 144 category options. How can this form be adjusted to work with SMS reporting?

was invited to participate in a three weeks field visit in Kigali in August 2012. The purpose of this expedition was first and foremost to work closer with the practitioners at the MOH in Rwanda and include them in the process of designing the plain-text SMS service. Second, we also wanted to examine the current installed base surrounding the Rwandan HIS, and third, to identify obstacles concerning the implementation of the pilot. Finally, we wanted to set up a demo on a server located in Rwanda, which is configured to work with a local SMS messaging service provider.

5.3.1 Workshop

One of the challenges faced in Rwanda was to transform a complex form for monthly report of the activities for the community health workers. This is the new version of the form for the monthly CHW report mUBUZUMA. The form is illustrated in Figure 5.2 This form consists total of 144 data elements if you include all combinations of category options. The paper form contains sections for: Treating sick children, nutrition, vaccination and nutritional supplementation, maternal health, community-based nutrition, family planning, mortality, disease follow-up, supervision and meeting and drugs supplies. There are category options like gender, weight, age and more.



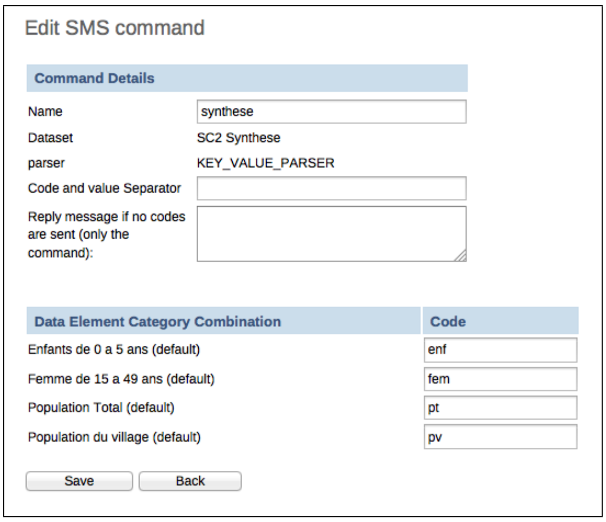
Edit SMS command

Command Details	
Name	nutrition
Dataset	SC2 B. Nutrition
parser	KEY_VALUE_PARSER
Code and value Separator	
Reply message if no codes are sent (only the command):	

Data Element Category Combination	Code
Number of children in green (MUAC_6-59)	gm
Number of children in green (Weight_age_6-59)	gw
Number of children in green (Total)	gt
Number of children in red (MUAC_6-59)	rm
Number of children in red (Weight_age_6-59)	rw
Number of children in red (Total)	rt
Number of children in yellow (MUAC_6-59)	ym
Number of children in yellow (Weight_age_6-59)	yw
Number of children in yellow (Total)	yt
Number of children receiving RUTF or SOSOMA followed up by CHWs (MUAC_6-59)	som
Number of children receiving RUTF or SOSOMA followed up by CHWs (Weight_age_6-59)	sow
Number of children receiving RUTF or SOSOMA followed up by CHWs (Total)	sot
Number of children referred to FOSA for possible malnutrition (MUAC_6-59)	refm
Number of children referred to FOSA for possible malnutrition (Weight_age_6-59)	refw
Number of children referred to FOSA for possible malnutrition (Total)	reft
Number of children with oedema (MUAC_6-59)	oem
Number of children with oedema (Weight_age_6-59)	oew
Number of children with oedema (Total)	oet

Save Back

Figure 5.3: Screenshot of SMS command made by the participants for monthly reporting on nutrition



Edit SMS command

Command Details	
Name	synthese
Dataset	SC2 Synthese
parser	KEY_VALUE_PARSER
Code and value Separator	
Reply message if no codes are sent (only the command):	

Data Element Category Combination	Code
Enfants de 0 a 5 ans (default)	enf
Femme de 15 a 49 ans (default)	fem
Population Total (default)	pt
Population du village (default)	pv

Save Back

Figure 5.4: Screen shot of SMS command made by the participants for monthly reporting on synthese

One issue regards whether this form already request too much information and may overburden the CHW. Another issue concern if this form applies to the concept of the minimal data set [24]. Nevertheless, the MOH wanted to try to use this form for SMS message reporting in the DHIS2.

The first approach during a workshop with the MOH participants was to create a SMS service for the monthly form and to divide the form into multiple SMS commands. The participants suggested a solution as illustrated in screenshots in Figure 5.4 and 5.3.

It is noteworthy that dividing the form into logical sections and different commands resulted in an uneven number of codes for each command. This is illustrated by the two figures. It was therefore suggested by the participants that one should have the opportunity to write more than one command into one SMS message in order to save messages. However, this idea was later abandoned. Even though this solution would save SMS messages, it was considered too complicated for the users with few use cases.

The codes proposed by the participants was 2-3 letter codes, mostly abbreviations of the data element name. The use of abbreviations might be of particular help for the English speaking users. However, many of the CHWs do not understand English. In this case, more letters would probably result in confusion for most of the users.

Another approach suggested by the participants was to combine the entire data element into one SMS command. The user would then fill inn values for all of the non-zero fields and skip the rest. The strength of this approach is shorter reports and consequently saving of time by not having the user to fill in 144 values every month. However, 144 values needs 144 unique codes, resulting in longer and more confusing codes.

The two suggested solutions are considered to be too complex for the users. It is hard to reduce this complexity without reducing the number of elements. Although, the technical limit of most phones can stretch 160 characters in each SMS message by merging multiple messages into one message, this will also need to be supported by the SMS service provider or the GSM modem used for the implementation. More importantly, observations during the workshop indicates that typing messages with more than 20 data elements is difficult on a low-end phone, even for the technically educated users. In sum, not all forms can be reduced to user-friendly SMS forms. In this example, the form would probably be possible to use on a computer or other device with more interactivity. A solution with so many data elements cannot be labeled as low interactive or simple [46].

The organizational unit structure in the national HIS instance of the DHIS2 consists of a national level, province, district and sub-district level. All health facilities, even some of the units higher up in the hierarchically, was implemented at the sub-district level. According to the participants, the reason for this structure was problems with aggregation of data to the national level when some facilities were located at the district level and others at the sub-district level. The CHWs report health data at the village level of the health system. Thus, the organizational unit hierarchy needs to be extended to cover the units below the sub-district to include the sector, cell and village level. This organizational unit structure can be extracted from available Excel spreadsheets containing lists of all CHWs in each district. Additionally, we also needed to create accounts for the CHWs in the DHIS2 and with the CHWs phone number. This information is also available in the Excel spreadsheets. However, these lists are not in a standardized format, so a lot of manual editing work would be needed in order to import this information into the DHIS2. There is currently no standardized way of doing this kind of bulk import of users and organizational units in the DHIS2[2].

5.3.2 Halt of the project

During the field trip to Rwanda we tried to send SMS messages to the BulkSMS messaging service provider in the UK. However, for some reason messages were not going out of the country. I tried to send both to the UK number and to a Norwegian number from two different MTN phones. This is a noteworthy observation because it provides information about the vulnerability of the mobile infrastructure regarding segmentation of the mobile networks. Moreover, network segmentation is a risk factor when using SMS service providers from outside the country.

In order to set up the plain-text SMS solution in the DHIS2, we needed either a modem or a service agreement with a SMS messaging service provider. Modems generally do not scale to the number of users in this project. The goal of this project is to implement a solution that scales for 60 000 CHWs. For that reason, we started the process of acquiring an account for sending and receiving SMS messages from a local SMS messaging service provider.

The SMS service provider in Rwanda (MTN) only supported the Short Message Peer-to-Peer (SMPP) gateway and not the HTTP gateway. I therefore implemented SMPP support in the DHIS2 during my stay in Kigali. In this way we would be ready to move forward with the project whenever the account of the SMS service provider would become available.

This process of acquiring an account form the local SMS service provider was started during the first week of the field work at the MOH and turned out to be a tedious process. The MOH already had an agreement with the operator MTN to be used for the RapidSMS solution. At first glance, coming to terms about an extended agreement seemed trivial. However, as weeks and months passed, the issue remained unsolved. The message we received from our contact at the MOH was that the MOH had to send a formal letter to the MTN and to agree upon some terms. I did not received any information about the terms or what kind of disagreement there might have been between the MTN and the MOH. Thus, the exact reason for why this project came to a halt remains unknown for the author of this thesis.

[2] An email thread about how to bulk import users into the DHIS2 database by using R and SQL scripts can be read at the web page: https://lists.launchpad.net/dhis2-users/msg01719.html

> (...) The MTN (Communication company) asked us to write a official Letter applying for SMPP. and we are in this process. Sorry for delaying! (...)

5.4 Phase 3: Demo for Uganda

To showcase the DHIS2 SMS module in Uganda, a demo service was set up during December 2012. The Demo server was running on a cloud computer provided by META. It consisted of a custom built version of the DHIS2, because some of the SMS functionality had yet to be committed to the DHIS2 code repository. The demo server also used the UK based SMS Messaging Service Provider BulkSMS through this phase.

5.4.1 How to link the mobile phone number to the organizational unit

In the implementation of the demo, the phone number for the user linked the reporter's phone to the organizational unit for which the data was reported. Thus, there should be only one user with an unique phone number serving as a link to the organizational unit. However, the process of creating the users lead to some concerns regarding the work load involved. It was considered less burdensome to register the phone number as an organizational unit property. One participant explained:

> (...) As of now the the report is recognized from the phone of the user assigned to that facility, but am foreseeing a situation where we may not want to create all these many users accounts but isteady use the contact details of the health unit under the orgunits. (...)

In the following, the participant elaborated on this matter by suggesting that phone numbers can be stored in the organization unit object inside the DHIS2.

> (...) I suggest under Contact information in the Org Unit management we add SMS reporting phone number, we can all for addition of more than one, like add a button that allow one to add more than one like it is with the automatic sms in the tracker. (...)

The proposed solution of looking up organizational units based on the phone number of the organizational unit can be implemented in addition to the current solution (using the phone phone number on the user). Further, it was made clear that creating a user account for every organizational unit may have the potential to stop the project in Uganda. One of the main concerns involves the bureaucracy when creating new user accounts in the national HIS instance of DHIS. The participant explained that this process was controlled by the MOH:

> (...) but the controls by MoH over the issuing using [user] accounts to facilities at this point (....)

Further, he argued for the use of the organizational unit property:

> (...) its easy to assign those numbers there [the organizational units] without necessary going through the user accounts bureaucracy (...)

However, one of the core member of the HISP Oslo team responded to this conversation and brought in a new perspective:

> (...) We want more DHIS users, and gradually they will get on better devices and start interacting with other DHIS 2 clients that need login. There is also an issue of easily identifying who entered the data, and using DHIS users also for sms reporting would be a lot easier as we can reuse how that is done for other data entry clients and store the user name with the values. (...)

This perspective involve the concern if the users in the future may change to other technologies when they for example get smart or feature phone or access to a computer. Thus, creating the users now would potentially give new opportunities in the future. It is also noteworthy to mention that this solution makes it possible to trace the person who entered the data into the system.

Four possible solutions

The first and probably the simplest solution would be to use the already existing organization unit phone number field to look up for the organizational unit. A main advantage is that this solution is simple to implement. Another advantage is that this solution will work in Uganda because the contact information field is not in use there. However, this solution has a disadvantage by only supporting one phone number for each organizational unit. Further, the phone number will appear as contact information to users of the DHIS2, which may confuse people to try to call the phone number in order to reach the facility. Finally, this solution might be shortsighted and not considered a solid solution (has the feel of a hack). Although it might work in Uganda, it may not work in all contexts. For example when a country is already using its contact information for other purposes.

The second proposal is to add a new attribute to the organization object. This could potentially be a multiple attribute, allowing multiple phone numbers to be associated with one organizational unit. This would involve making changes to the organization unit administrative interface.

A third possibility would be to use a new dynamic organization unit attribute. It would be possible to look up the attributes by adding rules for field names. One drawback might be that this solution does not support multiple numbers in one field, although more than one field could be supported. Creating multiple fields could be considered confusing for the user because all the fields will statistically appear when creating or modifying an organizational unit. This third solution is to implement new function for fetching organization unit objects based on dynamic attribute values in organization unit service.

The fourth solution would be to not implement any of three previous mentioned solutions, but rather continue to only support lookup of organizational units based on the users mobile phone number. This would support the argument that the users can continue to use of their accounts when accessing the DHIS2 by other devices in the future. However, it might lead to problems in regards of bureaucracy involved in the process of creating the user system in Uganda.

5.4.2 Select Organizational Unit in SMS message

Up to this point, the SMS module had only supported one organizational unit for each user. However, during demo implementation one participant dearly noted:

> (...) The SMS reporting number is currently the user's phone number and has to be assigned to to only one facility. This is already conflict that needs to be resolved. (...)

Thus, one phone may be used for reporting data from more than one organizational unit. One proposed solution was to implement a generic code for the organizational unit in the message format, so that it can be selected. To select the organizational unit, I suggested to use the organizational unit short code, which is an existing organizational unit property.

When a phone number in the system is associated with multiple organizational units, the system should send a list of organizational unit codes and full names to the user together with information about how to select one of the organizational units. The keyword for selecting an organizational unit is the codeword "org". It is noteworthy that there is no default organizational unit setting for the user. This would be considered a neat feature. If the user is associated with more than one organizational unit, and he or she reports data for the organizational unit with the code "Bo", then the SMS message would look like this:

```
Command org.Bo.a.1.b.2
```

5.4.3 Yes and no values

Two of the indicators in the Option B+ report is boolean:

- HIV kits available
- ARVs available

These two indicators are not going to be aggregated. The DHIS2 already have a data definition type for yes and no values. Although, the user could enter the more cryptic data base values “true” and “false”, this is not considered to be an adequate solution and is far from user friendly.

A separator needs to be used in order to support the letters in both keys and values. Further, definitions of yes and no values are needed. It should be possible to write both “yes” and “no” as values, as well as short forms “y” for yes and “n” for no.

Another solution suggested in order to avoid the need for a separator was to define “y” and “n” as values to be used in the same way as any numeric value. For example:

> (...) if the options are Y/N, then the codes are HIVY or HIVN (...)

In this example, the code for the indicator “HIV kits available” was “HIV”, while the code and value for no available HIV kits would be “HIVN” or “HIV N” (spaces are ignored).

Finally, the response message must convert the database values “true” and “false” to the more user friendly values “yes” and “no”.

5.4.4 Dot as a separator / delimiter

For the Option B+ Demo it was decided to use dot (.) as a delimiter between codes and values. The reason for selecting this delimiter was the fact that it was already used in the mTrack SMS message format. In this way we build on the installed base and the format may be familiar to users who have already used mTrack.

5.5 Phase 4: Implementation in Uganda

The implementation phase in Uganda started on the sixth of February 2013 when I traveled on my second field trip as part of the master thesis to Uganda. The trip was going to be four weeks of intense work. It involved attending many meetings, holding several presentations and observing workshops and training sessions. It also involved a field trip to Fort Portal, in the west of Uganda, almost at the border of Congo. During this trip three projects were started in collaboration with the local teams.

The rest of this section is organized by the presentation of these three projects. The first project involved SMGL and may be called the main project of the implementation. This was also the first project we started to work on during the field trip to Uganda. The second project was the PMTCT, also referred to as the Option B+ project. This is actually the same project as the one we followed in the previous phase and used for the demo. The third project involved reports on HIV Proficiency Testing from labs in Uganda. Following the project descriptions, I will describe the collaboration with UNICEF. Finally, I will summarize the experiences with the SMS Messaging Service Providers during the field trip to Uganda. Incidence which are reported by VHTs will be investigated by a SMGL investigation team to define the cause of death.

5.5.1 Project 1: Saving Mothers Giving Life

The first project we started was the weekly aggregated reporting on Mothers and Infant Mortality Reporting for SMGL. In this project, we are collecting two indicators by plain-text SMS messages and the reporting is conducted by the VHT. This project aims to have a working solution for the over over 4000 VHT members in the four SMGL districts in Uganda. The two indicators that will be reported by the VHT are the number of infants who died within 24 hours after birth and the number of women in reproductive age who died. Reported incidence will be investigated by a SMGL team to define the cause of death.

Configuring the Demo server

When arriving in Uganda, the first ting on the agenda was to setup a new demo server. Instead of first attending the meetings and then setup the demo, we wanted to show that we actually had a program that worked.

- Number of infants who died within 24 hours after birth (c)
- Number of Women in Reproductive Age who died (w)

Two indicators make up the format:

```
death c0 w0
```

The server was set up with a short code (8181). This was a shared short code which means that the short code is shared with other services. The messages are forwarded to our server based on the first keyword in the message. The demo server deployed on a cloud server running Ubuntu. It was running the latest snapshot of the DHIS2 (trunk). The national HMIS1 instance of the DHIS2 contains the hierarchical levels from the national level end down to HC. However, when the VHT workers in the SMGL are going to report data, they are reporting from the level of the villages. There is no official repository or data source for the organizational unit structure of Uganda or for the SMGL districts. However, SMGL has Excel spreadsheets which are used as a manual way of keeping track of VHT workers in each of their four districts.

We used two data sources to create the first implementation of the new organizational unit structure. The first data source was the organizational unit structure exported from the national HMIS1 instance of the DHIS2 in a XML export format. The second data source for the new organizational unit structure was the excel spreadsheets which included the following fields:

- Health Facility
- Parish
- Village
- Name (VHT)
- MTN Project (Phone number for MTN operator)
- WARID Project (Phone number for WARID operator)

A small Java Application was created to manipulate the exported Extensible Markup Language (XML) file from data source one adding to the new structure. The structure of the program was as follows:

1. Find Health Facility in XML
2. Find Parish

   If Parish do not exist add Parish to XML
3. Find Village

   If Village do not exist add Village to XML

However, there was a few issues with the data quality of the Excel. There were many rows in the Excel files with missing values like names of the district, health facility or village. The files had to be cleaned so that there was an exact match between the Health Facility Name in the XML and the Excel spreadsheet. There were many entries of each organizational unit in the spreadsheets because there are more than one VHT for each organizational unit. As a result, typos were common and needed to be corrected before the data quality was appropriate for the imports. The result of the process was an XML file that was imported to the demo server.

After the creation and import of the new organizational unit structure the new user accounts were created for all of the VHT workers in the Kabarole District. The new accounts were created by a batch operation for each VHT in the spreadsheet. Each account had the following attributes:

- Username
- First name
- Surname
- Mobile phone number
- Organization Unit
- A generated password (unknown to the user)

Some issues remained with the data quality of the contact information for the VHT in the spreadsheets. These issues concerned missing names for the organizational units and missing phone numbers. Another common issue was that only one name was entered in the name field, causing problems when splitting into the first name and surname.

First name and surname are obligatory properties for the user in the DHIS2 data model. Additionally, there were often more than one phone number for each VHT in the spreadsheet. In these situations, the first phone number was picked. However, we could have created one user for each phone number, but this was considered to be a less optimal solution at this point, at least for the demo. The generated password is a strong and unique password that is never given to the user. In this way the user can only access the system by using the SMS service, and this system does not require any authentication. The account can be opened for web login and other devices by the administrators by giving a new password to the user.

The purpose of the demo server was to present a system that worked and were able to create and import the users and the organizational unit structure from the existing infrastructure. Several iterations followed in cleaning data and importing new organizational units and users as we received spreadsheets for new SMGL districts. Nevertheless, the local implementation team were very pleased by having a live demo system up and running in less than 5 days.

First meeting with SMGL

When we arrived the SMGL Hospital in Kampala we entered a large hall full of waiting mothers, some pregnant and others with children. The room was filled with light coming from the windows at the opposite wall. On the other side of the windows is the backyard, where children are playing. The Hospital looks to be clean and well organized. We entered our names and the name of our contact in the visitor book at the reception. We follow the stairs up one floor and were were guided to the board room. The board room was well equipped with a projector, large table and solid leather chairs. The meeting participants included managers from USAID, Baylor and VHT coordinators from Baylor. The meeting started with a live demo of the SMS module. One of the VHT coordinators successfully submitted a report by using her own mobile phone. The new organizational unit structure as well as the imported VHT user profiles were then presented for the first time. After the presentation, a question and answer session followed with discussions regarding the implementation of the system.

Some issues were discussed more thoroughly than others. For example, how the VHT should organize reporting from villages with more than one VHT. It was concluded that one VHT should be responsible for sending in the report on behalf of the group. At the meeting it was suggested that it should be possible to add more than one user for each village. Another feature requested at the meeting was automatic reminders sent to users who have forgotten to send in their reports within a time frame. It was clear that the demo presentation was well received and Baylor wanted to plan training sessions for SMGL partners (Baylor, Infectious Diseases Institute, STRIDES, Marie Stopes Uganda (MSU)) as soon as possible.

Training for SMGL partners

This training session was for the VHT district coordinators who coordinate the VHT parish coordinators. The main purpose of this training was to introduce the system to the VHT district coordinators. Later these VHT district coordinators will in the future run workshops with the parish coordinators. Then, the parish coordinators will in turn train the VHT in the villages. The work for the VHT coordinators will involve maintaining the system, as well as supporting the VHT. The agenda for the training was as follows:

1. An introduction to the DHIS2
2. Crating and maintaining user accounts
3. Creating and maintaining organizational units
4. Send SMS to the DHIS2
5. Create and use report rate summaries
6. Create and use data set reports
7. Using web pivot table

During the training of the VHT district coordinators everyone were able to create their organizational units and users, as well as sending a SMS report from there own phone to the demo server.

One important observation and feedback during the training was the lack of functionality in the DHIS2 to search for users by mobile phone number. This feature may considered to be very helpful for the maintainers of the system. One particular use case would be to search for users based on a phone number when there is more than one user registered with the same number. Another scenario could be if users call or send SMS for support. In both of these cases it was considered to be easier for some of the participants to search for users by phone number. It was for example considered difficult to transcribe the name of the person that calls for support. The training was successful and the present manager even asked for "how fast can we roll out" the system.

UNICEF SMS gateway

The switch from SMSOne to the UNICEF SMS gateway also changed the short code from 8181 to 6767.

Training in Fort Portal

The training of the VHT was located in a health center Bukuuku HC, in the green and hilly landscape, 37 kilometers from central Fort Portal. There we met the VHT workers who received training in how to report health data by SMS messages. As part of our team, a Baylor VHT team leader conducted the training at the Bukuuku HC. He was trained in using the system earlier the same day and was given the training material. Ten VHT workers were gathered in a large room in HC. At the beginning of the session everyone introduced themselves and their role. Then, we asked some questions to find out how familiar the VHT workers were with using SMS messages for communication and other services. The following answers were provided:

1. Three out of ten VHT workers had no previous experience in using SMS messaging

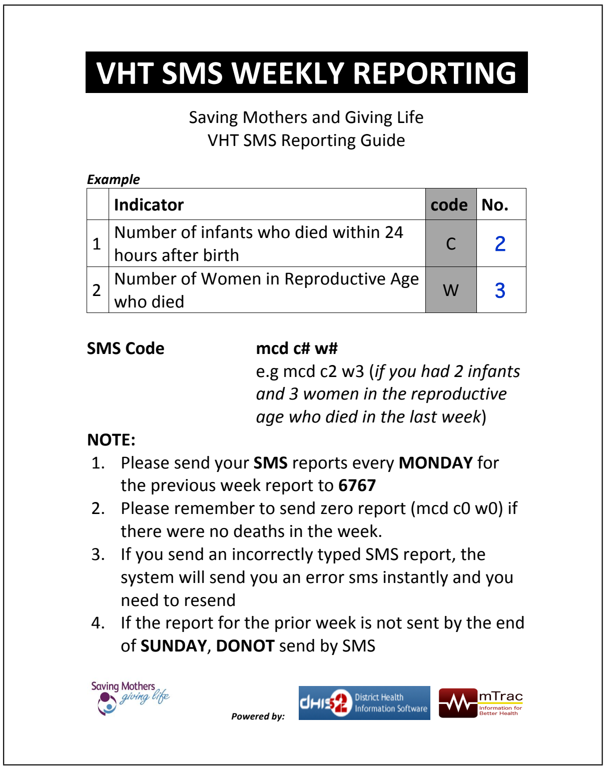
2. The VHT workers have free calls within a closed user group

Three out of ten VHT workers had no previous experience with using SMS. Although, more than half of the VTH workers had some experience with using SMS, I expected them to be more familiar with the technology. One of the factors that might be explaining this is the fact that the VHT workers get free airtime to call members of their closed user group, including other VHT workers, HC and hospitals, but the deal does not include sending free SMS messages within the group. During the training session we also had other interesting observations:

1. A majority of the VHT workers had wrong phone numbers in the system, a problem originating from the Excel files used for the import of the users

2. Updating the phone numbers for the users accounts in the DHIS2 can be difficult when the network is limited

3. Some phones had erroneous SMS messaging settings



VHT SMS WEEKLY REPORTING

Saving Mothers and Giving Life
VHT SMS Reporting Guide

Example

	Indicator	code	No.
1	Number of infants who died within 24 hours after birth	C	2
2	Number of Women in Reproductive Age who died	W	3

SMS Code **mcd c# w#**
e.g mcd c2 w3 (*if you had 2 infants and 3 women in the reproductive age who died in the last week*)

NOTE:

1. Please send your **SMS** reports every **MONDAY** for the previous week report to **6767**
2. Please remember to send zero report (mcd c0 w0) if there were no deaths in the week.
3. If you send an incorrectly typed SMS report, the system will send you an error sms instantly and you need to resend
4. If the report for the prior week is not sent by the end of **SUNDAY**, **DONOT** send by SMS

Saving Mothers giving life *Powered by:* DHIS2 District Health Information Software mTrac Information for Better Health

Figure 5.5: Saving Mothers and Giving Life VHT SMS Reporting Guide

4. The mobile phones were in some cases overloaded with spam and advertisement messages from the network operator. Thus, the phones would not receive the feedback messages before messages were deleted from their inbox

5. All VHT workers were able to send a correctly formatted SMS during the session

6. The VHT workers who first mastered the task showed an extraordinary helpfulness towards the VHT workers who were not that successful in their first attempt of sending the report

7. At least one phone had predictive text format set making it difficult to write commands and codes

The first observation concerned the quality of the data used for the creation of the user accounts. The data source either contained the wrong phone number or we picked the wrong number if there were multiple numbers listed for one VHT worker. This issue should be underscored in the training material, so the VHT leaders knows how to act when the system sends the response “The phone number is not associated to any orgunit”.

The second observation illustrates two points. First, the SMS system tolerates bad network connections better than mobile data traffic. Thus, there were no problems sending SMS messages at the training site.

However, we did find 3G network in one corner of the room, and we were able to update the users accounts with their new and correct phone numbers. We still saved some time, because we did not have to go through the process of creating the user accounts. Second, we observed that the search for user functions in the DHIS2 needs to be extended to also include phone number as a searchable property. This will make it easier to check whether or not the user accounts are in the system with the correct phone number.

The third observation is a little bit difficult to troubleshoot. Hopefully this problem is not very widespread. Only one out of ten VHT workers had this problem at our training. However, this is a problem that is likely to occur at some rate and the help desk personal will need to address. Luckily, the VHT received their phones from Strides and were the same phones, so creating a checklist for its configuration should be doable.

The fourth observation regards the fact that the networks in Uganda are loaded with massive amounts of advertising spam messages. There are at least three problems with this. First, the users may not pay attention to incoming messages in their in-boxes because all the messages they usually get are advertisement messages. Second, their in-boxes may be filled up with messages and this will block the phone from receiving any new SMS messages. Third, users may send SMS messages to the systems and fail to receive feedback messages. It is also noteworthy that this may limit the usefulness of reminders and bulk messages sent from the system to the VHT workers.

The fifth and sixth observation shows that all of the VHT workers at the training site were able to compose and send a correctly formatted SMS after first attending a 30 minutes lecture and reading the handouts. In addition, about half of the VHT workers were able to send a correctly formatted SMS to the system at their first attempt of sending a SMS message.

The VHT workers who managed to send the report at the first attempt started to help out the other VHT workers spontaneously and without our encouragement. Almost all of the VHT workers were able to compose and send the structured SMS message without help from us in the process. However, we had to help users with a wrong phone number in the system and people with erroneous SMS messaging settings on their phones.

The seventh observation concerns problems with the text format. When the predictive text format was enabled on the phones it was difficult for the user to write in the structured message format. This was especially evident when the key words and codes are not words in the dictionary, for example, when using abbreviations for commands and code. The command used in this test is for example âĂIJmcdâĂİ. The users who are not familiar with using SMS messages in their everyday life may not know about this setting, and this might cause a great deal of frustration and stress when composing their reports. However, the sixth observation is that the VHT workers displayed an extraordinary willingness to help the other VHT workers. Hopefully, their willingness to help others may also be a valuable resource for solving problems like these in the future.

None of the VHT workers had heard about the system called mTrack. However, when we asked the HC statistician she told us that she used the system to report on the Health Unit Weekly Surveillance form (HMIS 033B) and described the mTrack system to be "very easy to use". The way she used the system was to first put in the numbers in paper based forms before she composed the structured SMS message based on the form (see Figure 3.7). She kept all the completed paper forms in a binder. The health center also used a computer (running on solar power) for running a local instance of OpenMRS, which is a system used especially for managing patient records for HIV patients. This computer was not connected to the Internet.

Implementing the production server

When implementing the production server, one of the most important task was to finalize the organizational unit structure. A new import was conducted using the same tools developed when setting up the demo server. Most of the settings were the same, but the the parish was excluded from the organizational unit structure. The new structure locate the village directly underneath the HC in the organizational unit structure. There are two main arguments for doing this: First and foremost, some HC may serve the same parish which would lead to duplication of the parishes even though the parishes should be located underneath HC in the organizational unit hierarchy . Second, leaving out the parishes actually makes the structure less complex, because of the few villages in each HC. We also acquired Excel spreadsheets for all the four SMGL districts. After data cleaning, the new organizational unit structure was imported and new user accounts were created. The import counted 3044 villages in four districts and the 4300 VHT user accounts were created.

META provided the server used for the demo and continued their support by also providing the production server. The domain name "dhis2sms.ug" was acquired and setup. Both incoming and outgoing SMS configurations was setup to work with the mTrack SMS gateway.

Observations of incoming SMS messages

Two weeks after the program was initialized, nearly 300 VHT workers had submitted reports by using the SMS service. Some received personal training, while others received instructions broadcasted by the send SMS functionality in the DHIS2. The incoming messages have been monitored and errors or mistakes have been followed up by replying SMS messages or calling the VHT workers to help them correct their errors. It is important to note that the messages forwarded to the DHIS2 from mTrack must start with the commands "mcd" or "pmtct". Consequently, there can be messages that never reach the DHIS2. If we include all messages from the testing, training and demo sessions, then the total number of messages are about 3500 messages. In the system logs for incoming SMS messages we observed the following errors from the VHT workers:

1. Writing a narrative after the commands
2. Identifying themselves or the name of people who have died in the message
3. Sending the same message multiple times
4. Confuse the letter "O" and the numeric value zero
5. Confuse the letter "M" and the letter "W"
6. Confuse the expression sign (!) and the numeric value one
7. Adding hyphen, dots or comma signs instead of white spaces
8. Writing the phone number of the service number within the message
9. Reporting zero deaths but writing narrative about a mother and child who have died in another week
10. Writing narrative messages without spaces or other separator between words
11. Missing white space after command

See Appendix A for example messages.

Current status

The system is now being rolled out in all four SMGL districts and targets 3000 VHT workers who are supposed to send in weekly reports.

5.5.2 Project 2: Prevention of Mother to child transmission of HIV

The second project started in Uganda and involves weekly reporting of data for the PMTCT of HIV program. This program is run by USAID, CDC, and the MOH.

This project share the server with SMGL (dhis2sms.ug). This was possible because USAID and CDC are both SMGL implementing partners. UNICEF also provides mTrack SMS gateway for this project and supports the project with free incoming and outgoing SMS messages.

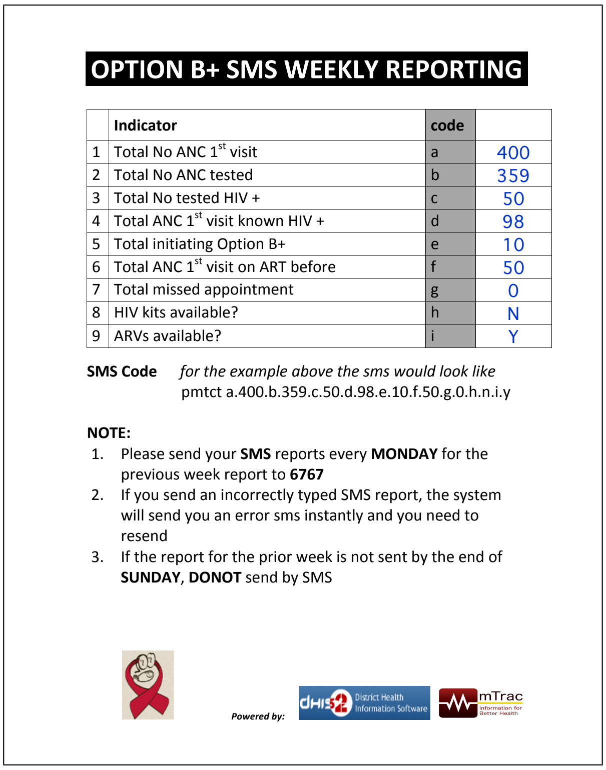
During the last week of the field trip, evaluation officers from CDC and USAID implementing partners were trained in using the SMS system in the DHIS2. I was present at one of these trainings. The officers are responsible for training data reporters at the HC and to create accounts for them in the DHIS2.

The project introduces weekly reporting of 9 data elements for Option B+ in Uganda by plain-text SMS. This is reported by the HC and hospitals, and is piloting in 2,400 implementing facilities across Uganda. Full scale reporting is expected to start in 2013. The following data values are collected:

- Total No ANC 1st visit
- Total No ANC tested
- Total No tested HIV +
- Total ANC 1st visit known HIV +
- Total initiating Option B+
- Total ANC 1st visit on ART before
- Total missed appointment
- HIV kits available?
- ARVs available?

The SMS format is a little bit more complicated than the one from the SMGL project. We need to define a separator, because of the yes and no value type. It was decided that we should use a dot as a separator, which is in line with what the mTrack system does. An example of the message format looks like:

```
pmtct a.400.b.359.c.50.d.98.e.10.f.50.g.0.h.n.i.y
```



OPTION B+ SMS WEEKLY REPORTING

	Indicator	code	
1	Total No ANC 1st visit	a	400
2	Total No ANC tested	b	359
3	Total No tested HIV +	c	50
4	Total ANC 1st visit known HIV +	d	98
5	Total initiating Option B+	e	10
6	Total ANC 1st visit on ART before	f	50
7	Total missed appointment	g	0
8	HIV kits available?	h	N
9	ARVs available?	i	Y

SMS Code *for the example above the sms would look like*
pmtct a.400.b.359.c.50.d.98.e.10.f.50.g.0.h.n.i.y

NOTE:

1. Please send your **SMS** reports every **MONDAY** for the previous week report to **6767**
2. If you send an incorrectly typed SMS report, the system will send you an error sms instantly and you need to resend
3. If the report for the prior week is not sent by the end of **SUNDAY**, **DONOT** send by SMS

Figure 5.6: Option B+ SMS Reporting Guide

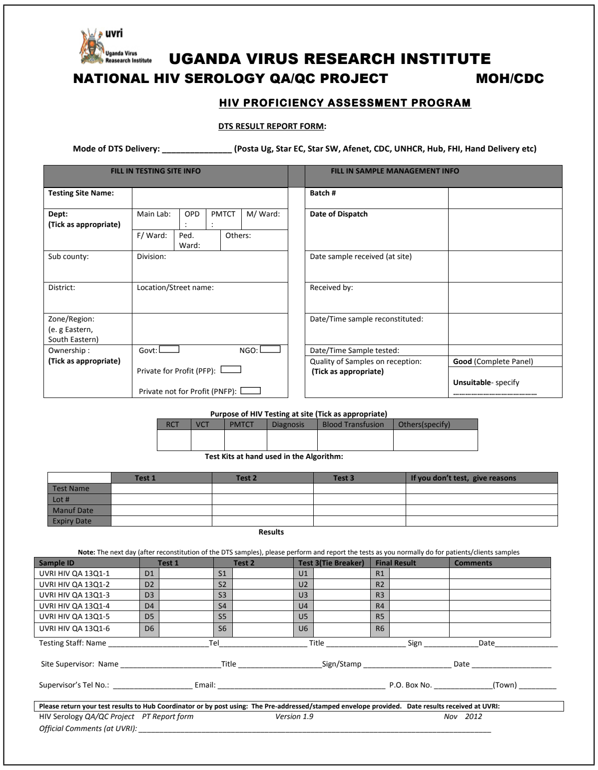
Observations of incoming SMS messages

These messages are from the training sessions and not from actual reports. The trained persons can be described as a highly competent staff who are familiar with using their phones . They all received the "Option B+ SMS Reporting Guide", illustrated in Figure 5.6 for their training. By investigating the system logs after training the following user errors were observed:

1. Using dot as a separator between command and the first code
2. Missing dots between some of the codes and values
3. Sending in the same message multiple times

The observations shows that using multiple separators in one message confuses the user. The second observation might be explained by the complexity of the structured SMS message when many indicators are reported.

The third observation regards users sending the same message multiple times from the same phone number. This can probably be explained by the lack of response message from the system due to some problems with the mTrack service during the training session. See Appendix A for example messages.



uvri
Uganda Virus Reasearch Institute

UGANDA VIRUS RESEARCH INSTITUTE

NATIONAL HIV SEROLOGY QA/QC PROJECT **MOH/CDC**

HIV PROFICIENCY ASSESSMENT PROGRAM

DTS RESULT REPORT FORM:

Mode of DTS Delivery: _______________ (Posta Ug, Star EC, Star SW, Afenet, CDC, UNHCR, Hub, FHI, Hand Delivery etc)

FILL IN TESTING SITE INFO		FILL IN SAMPLE MANAGEMENT INFO	
Testing Site Name:		**Batch #**	
Dept: **(Tick as appropriate)**	Main Lab: / OPD: / PMTCT: / M/ Ward: / F/ Ward: / Ped. Ward: / Others:	**Date of Dispatch**	
Sub county:	Division:	Date sample received (at site)	
District:	Location/Street name:	Received by:	
Zone/Region: (e. g Eastern, South Eastern)		Date/Time sample reconstituted:	
Ownership : **(Tick as appropriate)**	Govt: ☐ NGO: ☐ Private for Profit (PFP): ☐ Private not for Profit (PNFP): ☐	Date/Time Sample tested:	
		Quality of Samples on reception: **(Tick as appropriate)**	**Good** (Complete Panel) / **Unsuitable**- specify …………………………………

Purpose of HIV Testing at site (Tick as appropriate)

RCT	VCT	PMTCT	Diagnosis	Blood Transfusion	Others(specify)

Test Kits at hand used in the Algorithm:

	Test 1	Test 2	Test 3	If you don't test, give reasons
Test Name				
Lot #				
Manuf Date				
Expiry Date				

Results

Note: The next day (after reconstitution of the DTS samples), please perform and report the tests as you normally do for patients/clients samples

Sample ID	Test 1		Test 2		Test 3(Tie Breaker)		Final Result		Comments
UVRI HIV QA 13Q1-1	D1		S1		U1		R1		
UVRI HIV QA 13Q1-2	D2		S2		U2		R2		
UVRI HIV QA 13Q1-3	D3		S3		U3		R3		
UVRI HIV QA 13Q1-4	D4		S4		U4		R4		
UVRI HIV QA 13Q1-5	D5		S5		U5		R5		
UVRI HIV QA 13Q1-6	D6		S6		U6		R6		

Testing Staff: Name ________________________Tel____________________ Title __________________ Sign ____________Date______________

Site Supervisor: Name ________________________Title ____________________Sign/Stamp _____________________ Date ___________________

Supervisor's Tel No.: ___________________ Email: ____ P.O. Box No. ______________(Town) _________

Please return your test results to Hub Coordinator or by post using: The Pre-addressed/stamped envelope provided. Date results received at UVRI:

HIV Serology *QA/QC Project* *PT Report form* *Version 1.9* *Nov 2012*

Official Comments (at UVRI): ____

Figure 5.7: Paper based PT result report form

5.5.3 Project 3: HIV Proficiency Testing Quarterly Report

The third project is the Uganda Virus Research Institute HIV Proficiency Testing Quarterly Report. In this project the Proficiency Testing (PT) is carried out in labs in CDC districts and the lab technicians report back to the Uganda Virus Research Institute (UVI) at CDC by a plain-text SMS solution in the DHIS2.

Every quarter the UVI team sends one PT panel consisting of six individual-matrix dried-blood spot (DBS) specimens to all labs. The labs are supposed to test the DBS specimens and send the results back to the UVI team. Currently, the results are supposed to be written in a paper form and sent back to the UVI team in pre-stamped envelopes provided with the PT panel. Even so, they rarely received the reports from the labs. 3774 PT panels were distributed in the second quarter of 2013, but only 24% of the labs returned their results. The paper form is a rather complex form. See Figure 5.7 and notice that facility and personal information have to be entered in the paper form every time the lab reports their data.

All labs are supposed to test all the DBS specimens successfully and send back the correct result. When the UVI teams check the labs results against the answer key and discover a mismatch, then they will investigate why this occurred.

Server setup

The server has its own organizational unit structure and is seen as an internal CDC tool. The users base is also different from the one reporting in Option B+ and SMGL. Additionally, CDC wants to operate and maintain its own instance of the DHIS2 in the future to build local capacity and to achieve sustainability. However, during the initial stages of piloting and roll out of the system, the CDC Uganda wanted progress and therefore decided to use a cloud server which is provided by the HISP team in Oslo. The server is temporarily running on the URL "earth.dhis2.org/dhis".

This instance is using Text to Change[3] as a SMS messaging service provider. This is a standard Hypertext Transfer Protocol (HTTP) SMS Gateway.

Organizational unit structure

In this project, the labs and the lab personnel report data. Meaning that the organizational unit structure must include individual labs. Because there can be more than one lab in each health facility, the system will only allow one report for each organizational unit each quarter. Two labs in the same facility would result in an overwrite of previously entered reports.

CDC was able to provide an Excel spreadsheets which contained the mobile phone number of the person who are performing the test at each lab, as well as the phone number, testing site and district. The organizational unit structure and the users were imported into the new DHIS2 instance by making some small modifications to the tools created for importing the organizational unit structure in the SMGL project.

The import was conducted in two turns. The first import counted 540 lab technicians and 554 organization units consisting of HC, hospitals and labs.

Simplifying the form to fit into a SMS message

The paper based PT form (see figure 5.7) is a complex form with a lot of input fields. On of the advantages of using a computer system is that information regarding the testing site does not need to be entered because it is already linked with the reporting phone number. The total number of data elements would have been 24 data elements, if all data for Test 1, 2, 3 (Tie Breaker) were included in the SMS together with the final result. During the meeting, one of the practitioners tested to write 24 data elements into one SMS message and send it to the live system. This proved to be a quite complex and difficult task. It was therefore decided that intermediate results should be excluded from the report.

The Sample ID, which is an identifier for each of the DBS, was also excluded because the samples sent to each lab are already registered in the system. It is sufficient that the samples were numbered 1-6. Finally, it was decided to only collect the 6 data elements of the final results of the tests.

[3] http://www.texttochange.org/

The data elements can either be positive or negative, which is represented as a textual data type. The value entered should be either “pos” or “p” for positive HTV tests and “neg” or “n” for negative HIV tests.

The new command named “Labdts”, an example of the format would be:

```
labdts r1.neg.r2.pos.r3.neg.r4.pos.r5.neg.r6.pos
```

Future work at CDC

Bimonthly reporting for Cluster of differentiation 3, 4 and 8 PT is a an upcoming addition to the HIV PT reporting service. The following six indicators are collected:

- Final Result CD3 absolute (3a)
- Final Result CD3 percent (3p)
- Final Result CD4 absolute (4a)
- Final Result CD4 percent (4p)
- Final Result CD8 absolute (8a)
- Final Result CD8 percent (8p)

The proposed SMS format worked out by the local CDC team is:

```
labneqas 3a.999.3p.88.4a.777.4p.66.8a.555.8p.44
```

Additionally, CDC has expressed an interest in a decease outbreak surveillance using the DHIS2 SMS system. This decease outbreak module will collect the three indicators Viral Hemorrhagic Fevers (including Ebola Hemorrhagic Fever), Tuberculosis and Cholera. This module is still in the planning stages at the time of writing this thesis.

5.5.4 UNICEF collaboration

UNICEF agreed to support our project by providing free incoming and outgoing messages using their short code (6767). This is an UNICEF exclusive short code only to be used for reporting data. One of the advantages of sharing the same short code is to avoid confusing the users of the DHIS2 and mTrack systems by providing one short code for reporting weekly program specific indicators and monthly reports to the MOH.

mTrack is actually using two SMS messaging providers. First they have a contract with Airtel, which is one of the network operators. Second, UNICEF uses another SMS messaging service provider to distribute messages to other networks. Ugandan telecoms does not have number portability, so it is possible to route the SMS messages to the correct network by just analyzing the number structure of the phone number.

	TEXT TO CHANGE	SMSONE	UNICEF
Orange	Working	Sending	Working
MTN	Working	Working	Working
Warid	Working	Working	Working
Airtel	Working	Not working	Working
URL	Working	Not tested	Working

Table 5.2: Which networks work with which SMS service provider in Uganda. Working means that DHIS2 is able to both send and receive SMS messages.

We met the representative from the UNICEF during the third week of the field trip. We outlined how the mTrack Gateway implementation could be implemented in the DHIS2 system. For example, UNICEF wanted to avoid "hammering" of their mTrack server when the DHIS2 server is sending bulk messages to many users at once. We agreed upon a mTrack specific protocol for integrating mTrack and the DHIS2 SMS services. However, in the meeting I emphasized that we would like the integration point to be within the RapidSMS system rather than mTrack. One of the core architects behind RapidSMS was also in the meeting and he agreed that we should follow up on this issue.

5.5.5 SMS Messaging Service Providers in Uganda

There are many SMS service providers in Uganda. In this project we started out by using SMSONE. Even though SMSONE claimed to support all networks, it turned out to not be the case. We therefore decided that it was time to search for a new SMS messaging service provider. In order to find new providers we sent an email to a list of providers in Uganda. The email included a list of questions and technical requirements. About three out of ten contacted companies responded to this request. Among these three providers CDC Uganda chose the company named Text to Change. It is noteworthy that none of the companies could support the requirement of Basic HTTP Authentication without placing the username and password in the URL.

Table 5.2 was created to keep track of which service provider that works with which network. In Table 5.2, the service providers are listed in the first row and the network operators in the leftmost column. UNICEF is listed, although they are not strictly speaking a SMS Messaging Service Provider. It is important to note that the tests have not been conducted at the same time. However, this table has proven to be a useful tool in keeping track of which networks the providers actually support. The providers do not always support all the networks they claim to support.

5.6 The software artifact

One of the contribution from the work with this thesis to the HISP network is the creation of the software artifact. The artifact was created as a module inside the DHIS2. The main contributions to the DHIS2 involves following elements:

- an extended support for SMS messaging service providers
- a queue for incoming SMS messages
- an asynchronous SMS message handler
- a parser that parses SMS messages
- a web user interface for setup inside the DHIS2
- identifying organizational unit by phone number entered in the user account

There was already an existing SMS Gateway in the DHIS2 before this project, but this gateway only supported outgoing SMS messages for SMS messaging service providers and had no SMPP support. Thus, support for both SMPP and incoming messages to the DHIS2 from SMS messages providers over HTTP was added.

Precautions has been taken in order to avoid overload of the DHIS2 server when the server receive massive amount of messages. For example, the parser run by an asynchronous service. Persistence has also been added to the incoming message queue, so messages should not get lost if the server go down, for example due to power outage.

The key and value parser have been implemented to support the use of a separator (or delimiter). A separator is needed when the report includes data elements which is not numeric. For example "yes/no" and text values. The separator can specified for each SMS command. An example of the syntax with a separator can be found in the Option B+ project (see for example Figure 5.6), while the syntax without a separator can be found in the SMGL project (see for example Figure 5.5).

The default period for reporting is the previous period. However, report for the current period is also possible by enabling this option in the SMS command editor. Further, the user can also specify the period in the SMS message.

Further, the module for the parser has been implemented with generalizability of the software artifact in mind. Thus, it is possible to implement new types of parsers and add them to the list of parsers, in the web user interface for adding new commands (see Figure B.5). Further, a web interface for edit commands and add codes for data elements in the SMS form (see Figure B.7). A list of existing SMS commands (see Figure B.6) has also been created. Thus, the module can be configured and setup under the "Maintenance" section in the DHIS2. The module has reached a level of maturity that also allowed it to be included into the DHIS2. The software artifact has been tested thoroughly in Uganda. Further details on the software artifact can be found in Appendix B.

5.7 Summary

In this chapter I first presented three possible solutions for how to integrate the DHIS2 and the SMS infrastructures. A spacial focus was given to integration, interoperability and the rise of complexity. Then, the four ADR phases were presented.

The first phase gave us insight in how the SMS format was designed, some initial architectural decisions and finally the setup of the first demo server. The second phase took us through the Rwanda case, a project which later came at halt for unknown reasons.

The third phase describes the first demo server for Uganda. This phase describes discussions regarding how to link the phone number to the organizational unit in the DHIS2, and finally how we ended up with the initial solution of linking the organizational unit by the user. Later, we also showed how the user is able to select an organizational unit in the SMS message, "yes/no" values and the use of separator characters between keys and values in the SMS message.

The fourth face covers the implementation of the three projects in Uganda. It provided a detailed description of the field trip and collaboration with multiple NGOs and implementing partners. The highlights were the observations during the training sessions with the VHT workers and the observations regarding incoming messages committed by the VHT workers in the following weeks. Further, we also started up the PMTCT project, which is piloting the system in 2400 HC throughout Uganda. The final project describes the startup of the CDC Uganda HIV PT Quarterly report. It is noteworthy that all the three project involved the use of existing infrastructures like Excel spreadsheets for the implementation.

The two following sections covers the partnership with UNICEF in Uganda and the SMS messaging service providers in Uganda. These are important actors in the local infrastructure environment, which are all related to each other. Finally a description of the software artifact was provided and how the DHIS2 and SMS infrastructures were integrated.

Figure 5.8: A VHT worker at the Bukuuku HC has successfully sent in the report and received a response message from DHIS2 using her own mobile phone.

Chapter 6

Discussion

In this thesis, the ADR method [47] has been used to create an innovative mobile health implementation for remote data collection using SMS infrastructure in the DHIS2. Research using the ADR method should result in a theory-ingrained artifact. The theories utilized in this thesis are information infrastructure theory with the use of bootstrapping and cultivation mechanisms [30] [31] [32] as guidelines. The term generativity [53] is used as a property describing the developed software artifacts ability to find new uses. Through the work with this project we acknowledge that the complexity of integration increases with the involvement of organizational and political actors [26]. Moreover, the project is part of a larger network of action called the HISP network [23].

In the work with this project we have created a theory-ingrained software artifact based on the theories mentioned above. The development of the software artifact and implementation in Uganda follows the principle bootstrapping as proposed by Hanseth and Lyytinen [32]. They suggest five rules for bootstrapping of a software artifact into an existing infrastructure.

The first rule is to design the software artifact for direct usefulness. The term "direct usefulness" is interpreted to mean that the software should address some specific user needs and be useful within a short period of time [15]. The software artifact should also be useful without an existing user base. The implementation addresses the need of several NGOs and the MOH to collect health data. The three projects in Uganda serve as examples showing the direct usefulness of the software artifact. The first project collects data on mother and child maternity for SMGL in four districts by the use of the DHIS2. The second project utilizes the software artifact for collecting data regarding performance monitoring of HIV test labs for CDC Uganda. The third project collects data from PMTCT indicators for MEEPP. These are all examples of direct usefulness of the same software artifact. Further, the software artifact was usable already from the first prototype and was able to collect data into the DHIS2 by using SMS messages.

The second rule is to build for the software artifact based on the existing installed base. Integrating the software artifact with the existing DHIS2, SMS, mTrack and VHT infrastructures accomplishes the second rule.

Further, both the project in Rwanda and Uganda started by analyzing the existing installed bases in each country. Following this analysis, the next step of action was to integrate the artifact to already existing infrastructure in each country. The integration between the infrastructures in Uganda is illustrated in Figure 6.1. Both solutions are based on using existing SMS infrastructure for transport. The SMS messaging service providers were used as gateways to the SMS infrastructure. This is exemplified when the project implements support for the SMPP in the absence of HTTP support in Rwanda in order to use the local SMS messaging service provider. Further, we also utilized the existing installed base and avoided large investment in equipment when utilizing existing VHT phones for implementing the SMGL solution in Uganda. We also used the existing installed base when the SMGL and MEEPP projects used mTrack as a gateway to the SMS infrastructure. In addition, we used the existing installed base when we recycled SMS format of the mTrack system by using a dot as a separator in the PMTCT project in Uganda. Thus, we cultivated the existing message formats and used it as more general standard separator between keys and values in SMS messages in Uganda.

Hanseth and Lyytinens third rule is to use persuasive enrollment tactics to expand the installed base. The term "persuasive enrollment tactics" is interpreted as taking action and enroll new users of the system. In this project we have actively expanded the user base by having workshops for participants and end-users. We have also integrated our system with existing infra-structural artifacts containing user information (such as the Excel spreadsheets), thus rapidly expanding the user base.

The fourth rule is to make the organization of the IT capabilities simple. When we implemented the SMS module inside the DHIS2 we selected a simple solution with low complexity for the local IT organization. Further, a web user interface was developed where the user and practitioners can create their own SMS forms for their data sets, thus, lowering the need for technical knowledge.

The fifth rule states that the designers should organize modularly capabilities into loosely coupled sub-infrastructures. The software artifact of this project is loosely integrated with the SMS infrastructure. The solution is considered to be both modular and extendible. It would be possible to modify the current module to receive messages from other gateways with only smaller modifications. Further, we have to some degree solved the problem with lock-ins by supporting multiple types of SMS gateways. For example, in order to change to another SMS messaging service provider, one only has to change a few properties of the SMS gateway configurations within the DHIS2 web user interface. However, the problem of short codes being locked to the SMS messaging service providers is still present in many settings.

The dynamics of the web and mobile infrastructures are very different, especially in the SMS infrastructure. By having Internet on a mobile phone provides access to the whole Internet with its open ended and transparent architecture. Thus, it does not matter which network the mobile phone is connected to because it can still connect with any other nodes in the Internet. On the other hand, this is not the case for the SMS Messaging Service providers. The service operators need to have contracts and integration with every Mobile Network Operator in order to deliver messages to mobile phones within the respective networks. This is also the case for short codes, which is a four-digit service phone number. This code is only valid within the network of a single operator. So, in order to get a four-digit number to be reachable from all networks in a country, agreements are needed with every network operator within the country. No short codes available are valid for the entire world. However, a short code can be compared with a domain name on the Internet. This exemplifies the flexibility of the Internet infrastructure compared to the SMS infrastructure. An observation that underscores this point was when we found out that not all networks worked with all SMS messaging service provider when the system was tested in Uganda. It is therefore safe to claim that the SMS messaging is far less flexible than the use of data traffic.

There are a large number of stakeholders in the Ugandan health system. The differences in view and agendas are risk factors, which can increase the complexity involved in the process of integrating the systems. The political dynamics influencing the integration of the infrastructures is existent but is nevertheless hard to identify and control. The eHealth Moratorium in Uganda is a political actor. Two of the systems approved by the ministry in the Moratorium are the DHIS2 and mTrack. mTrack is the system appointed by the MOH as the tool for collecting health data by SMS messages. The DHIS2 on the other hand is the national HIS. The MOH has decided that data collected by mTrack should be available in the DHIS2. The integration of these systems has been difficult to accomplish, as described in the background. At the same time, both systems are actively developed and are clearly moving into each other domains. mTrack has developed a dashboard where users (NGOs) can access the information collected by mTrack in the web user interface. Even though this part is not open to the users at the time of writing this thesis, the NGOs were clearly invited by UNICEF to request the MOH to open access to these features at one meeting I attended with UNICEF and NGOs during the field trip. At the same time, this project confirms that the DHIS Mobile community is actively developing a SMS module that can handle some of the same tasks regarding remote data collection using SMS messaging as the mTrack system. In light of the eHealth moratorium, the DHIS2, mTrack and other approved (and not approved) information systems are political actors in the actor network. In Rwanda we had a working system that was ready to be integrated with the SMS Infrastructure and existing installed base in the country. However, the project came at halt and it was not due to technical issues. The project stopped at the organizational and political level. These observations support the "integration / interoperabilit" model, illustrated by Figure 2.1, in which complexity increases at the higher organizational levels of the health system rather than at the technical level.

The DHIS2 can be described as a generative software artifact that is highly customizable. Web browsers and devices like feature and smart phones can also be used to access the DHIS2 web user interface. In this project, simple phones were added to the list of supported devices enabling the use of SMS messages to interact with the system.

In the following, the added artifact will be illustrated as a generative software artifact in accordance with Zittrains definition [53] of generativity.

First, a generative artifact enables users to accomplish things that would be either impossible or not worth the effort to do without utilizing the artifact. I will claim that the software artifact has now opened new possibilities for collecting data by using the DHIS2 from a previously unreachable SMS infrastructure. Another project attempted to collect data with SMS messages by the use of an external system (mTrack). However, this earlier attempt to integrate mTrack with the DHIS2 has proven to be difficult in Uganda.

The second characteristic of a generative artifact is adaptability. As seen in the case study presented in chapter 5, the SMS solution in the DHIS2s is adaptable. The number of projects in Uganda and a range of uses of the artifact illustrate this feature of the software artifact. Generativity also implies that the software is adaptable to new contexts. By investigating the installed bases in both Uganda and Rwanda and by setting up a demo server in the UK, we have seen that the software artifact can be implemented in different contexts. Thus, the software artifact is not only designed for use in Uganda.

A generative artifact should also be easy to master. In our case, this would mean that the software artifact should be easy to setup in any context. In our study, the practitioners were able to configure the solution and create new SMS forms for collecting data in Uganda.

The fourth characteristic of a generative artifact according to Zitterain is accessibility, meaning that the software artifact should be easy to acquire and setup. The DHIS2 is an open source project and the application and source code is freely available for download from the web page of the project. Thus, it is easy to obtain the software artifact. Most importantly, by making the artifact as a module inside the DHIS2, it will be available to the global DHIS2 community. Thus, most of the already existing DHIS2 implementations will be able to integrate with local SMS infrastructure by configuring a SMS gateway.

Interestingly, one of the main reasons for such a generative solution is the fact that we followed the bootstrapping mechanisms described above. Zitterain principles of adaptability and mastery of the software artifact can be viewed in light of Hanseth's fourth rule to make the organization of the IT capabilities simple. Consequently, there is a linkage between bootstrapping and generativity [32].

The integration of the web infrastructure and the SMS infrastructure may also be viewed as digital convergence. One often consider digital convergence in high resource contexts, in which several features often are combined into on device, for example the smart phone. However, in the present project and the background cases, we have another kind of digital convergence taking place in low resource contexts. The digital convergence in low resource contexts makes the web services like the DHIS2 available for simple phones with no data or application support. Thus, the DHIS2 and web based infrastructure converge towards the SMS infrastructures. Another similar example is when MTN Uganda makes Twitter available as a SMS messaging service. The low resource convergence makes it possible for users with simple phones to utilize services that previously were reserved for users with Internet access. The user is unable to switch technology and interact with the web infrastructure directly, so the SMS infrastructure must therefore converge with the web infrastructure enabling the users to utilize these new services with simple phones.

During the work with this project in Uganda we made several noteworthy observations. In the training sessions with the VHT workers and later in the logs we observed that although the VHT workers adapted to the new technology quite fast, there are still some issues that we need to address. The VHT workers composed SMS reports containing narratives and confusing letters, numbers and signs. They sometimes also failed to apply the syntax.

Prensky [44] uses the phrase digital natives and digital immigrants to describe a generation split between people grown up with digital devices like computers, video games etc., and those who have not. The research team in Oslo falls into the group digital natives and are first grade citizens of the digital age. However, we are creating systems for users who may never have used a computer system during their lifetime. This might explain some of the observations when the VHT workers interacted with the DHIS2. For example, when the VHT worker uses the letter O instead of the number zero (0) in the SMS report, it is an obvious mistake for a digital native. However, this might not be the case for a digital immigrant like the VHT workers. However, the most important observation during the field trip was that theses mistakes and errors in the SMS message were very hard to predict for digital natives. The strength of the ADR method is exactly that we take the implementation to the end-user and have the opportunity to observe these kinds of user interactions with the system. One of the actions taken was to contact the users directly and explain their errors in order to help them to compose a correctly formatted SMS message. However, work should investigate other solutions to deal with these kinds of errors in a more scalable manner.

Another observation found during the work with this project is the large amount of time used to implement the servers. In our case, this involved the import of the organizational unit structure and users for Excel spreadsheets. Records of the VHT workers in Uganda and the CHW in Rwanda were both kept in Excel spreadsheets. Further, the CDC Uganda also used Excel spreadsheets for their lab personnel journals. However, there are no easy / automated way to do these sort of bulk import tasks in the DHIS2. An ad-hoc application was created specifically for the task of importing these users and organizational units. Many of the methods used in this application can best be described as hacks or ad-hoc solutions. However, a refinement of such a product could be useful to avoid such ad-hoc solutions in the future. There have been many discussions on this topic, but no standardized solution is nevertheless available. Further, creating these kinds of ad-hoc import mechanisms demands a great deal of technical knowledge, programming skills and mastery of many different technologies because some of the tasks are done at the database level. Consequently, a standardized solution would be useful for both practitioners and implementers in general. Thus, a standardized solution for bulk imports would make the DHIS2 more generative.

One of the objectives of the HISP network is sustainability [23], which is defined as having something that works over time rather than for a limited timespan. The question is then whether or not sustainability is achieved. To answer this question, we need to look at the bigger picture. Because, we are not only working an achieving sustainability for the software artifact of this project, we are working for the sustainability of the DHIS2 in general. Throughout the project, we have expanded the HISP and DHIS2 network of action in Uganda. By expanding the installed base of the DHIS2 in Uganda, we strengthen the sustainability of the DHIS2 installed base in the country. Eventually, these and other local projects (in a global context) constitute the HISP network, thus, strengthening the global HISP network. Although, this project successfully integrated the two infrastructures, we have not yet achieved sustainability. Sustainability for this project in particular is achieved only when we continue to cultivate and improve the generative software artifact over time. However, all the projects in Uganda are planned to scale into full production and are not regarded as pilots per se.

In sum, the software artifact presented in this thesis can be regarded as a generative software artifact. The implementation of this artifact followed the method of bootstrapping. The project led to a convergence in the DHIS2 infrastructure towards the SMS infrastructure. In Uganda, this is exemplified by having the DHIS2 installed bases converge towards the SMS installed base and the VHT installed base. We have seen that the strategy of bootstrapping and cultivation of the existing installed base and creation of a generative software artifact proved to be effective when integrating the mobile SMS infrastructure and the DHIS2 web infrastructure. A link between bootstrapping and generativity of a software artifact was also proposed. A noteworthy observation indicates that the complexity of integrating the infrastructures increases in the organizational context. We also observed more inertia in the SMS infrastructure than in the more flexible web infrastructure. In addition, we considered how the VHT workers in Uganda adapted to the system. Further, we considered how the VHT workers could be viewed as digital immigrants with implications for research when the ADR researcher is a digital native. We also observed how lack of proper tools for bulk tasks, like import of organizational units and users, makes it more time consuming to implement the DHIS2. Finally, a discussion of how this project affects the sustainability of the DHIS2 in a global and local context was provided.

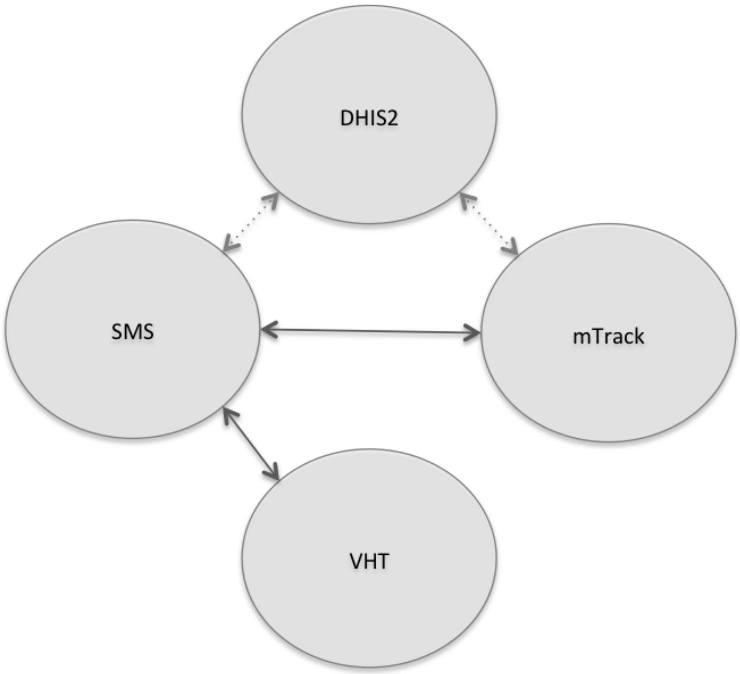


Figure 6.1: Ugandan health infrastructures. The solid lines represents integration between the infrastructures prior to the implementation. The dotted lines represent integration after the implementation.

Chapter 7

Conclusive remarks

In this thesis, some of the dynamics involved in integrating SMS and web infrastructures in low resource contexts have been addressed and discussed. The project involved extending the DHIS2 software for remote data collection by using SMS infrastructure. The ADR method was used for the development and implementation of this software artifact in low resource contexts. The present ADR study included two field trips with the aim of implementing remote data collection of health data for local stakeholders. The process of creating the software artifact was based on participative design during the project and resulted in a working module for remote data collection using SMS messaging by the DHIS2. The two infrastructures were integrated with few resources at hand by creating a generative software artifact, and further by using strategies such as bootstrapping and cultivating the existing installed base during the implementation stages.

The use of cultivation and bootstrapping strategies seemed to be particularly fruitful when integrating the two infrastructures in Uganda. During the project we encountered different dynamics that served to facilitate or obstruct the progress of integrating the two infrastructures. These dynamics operated at both the technical and the organizational levels of the health system. In this project, the SMS infrastructure was found to be less flexible than the web infrastructure. The generative approach focusing on the ease of mastery of the software artifact for the implementors and adaptability of the software artifact was a driving force for innovation. Thus, the generative approach spawned new projects for remote data collection using SMS messaging in Uganda.

As presented in the discussion, the use of concepts like generativity of the software artifact and digital convergence together with information infrastructure theories was found to be useful terms when discussing the process of integrating mobile and web health infrastructures in low resource contexts.

In this project, the combined approach using ADR method, cultivation and bootstrapping strategies was found to be successful in the process of integrating the two infrastructures. It is therefore recommended to focus on cultivation and bootstrapping of the existing installed base as a practical strategy for the integration of mobile and web health infrastructures in the low resource contexts.

As a result of this project, the DHIS2 is now closer to support the mHealth typology suggested by Sanner et al. [46] by expanding the boundaries of the DHIS2 infrastructure. Consequently, people that previously were unable to interact with the DHIS2 are now able to use the system. Hopefully, this may contribute to better health information in Uganda and other LDC.

One of the challenges in this project has been to find the optimal balance between the practical needs of the organizations and research activities. This is a demanding task, especially when taking sustainability into account. I often find myself wondering whether I should continue writing on this thesis or respond to an email or fix a newly reported bug. At the same time, it have been fruitful to use the ADR method to gather experience and knowledge of implementing the software artifact in unique settings.

Finally, I have the following suggestions for future work for both the DHIS2 project in particular and for this research field in general.

In this project we are creating systems for users who may never have used a computer system before. The users made some errors and mistakes that were discussed. I found it suitable to use the terms digital native researchers and digital immigrant users when integrating the two infrastructures to visualize the reality gap between the researcher and the research objects. After the integration of the two infrastructures, the stage is now set to do more research on data collection in low resource contexts using SMS. It is recommended to do more research on the topic of human-computer interaction [19] regarding data collection and SMS mobile infrastructure. The focus for this research could for example be how to best transform data collection forms to SMS forms.

Further, I would suggest to investigate more closely why the project in Rwanda failed. Although, we have some speculations about what might have happened in Rwanda, we would like more information about why this project came at halt. It might be that our software artifact was not adaptable enough (at the time unfinished) and did not have the right degree of leverage. It might also be as a result of political processes outside our field of view, but we do not know the exact cause for why the project in Rwanda came at halt. Nevertheless, failures are at least as valuable as success stories in providing knowledge about the dynamics involved when integrating two infrastructures. It is therefore recommended to do more research on the topic of why software projects fail even though the suggested methods and strategies has been applied.

I would also recommend further research to gather more information about the dynamics involved when integrating mobile and web health infrastructures in other LDC. One success story and one failure in implementing the software artifact in low resource contexts is not sufficient to draw firm conclusions when integrating the two infrastructures. Thus, a more complete picture of the dynamics involved in other LDC are needed. However, this project do provide some information about the processes that might facilitate or obstruct the implementation of a software artifact in low resource contexts. In addition, it might be of interest to investigate these processes in a low resource context outside the health domain, for example, in other public sector contexts such as agriculture.

Further, during the field trips I noticed a demand for a practical integration of the Excel infrastructure and the DHIS2 in both Uganda and Rwanda. A focus on the ease of mastery for the local administrators would ensure that the DHIS2 would achieve a higher degree of generativity when integrating the DHIS2 and Excel infrastructures. There are two potential outcomes when these two infrastructures are integrated: First, one of the infrastructures can replace the other. In this case there is no need for later synchronization/updates between the infrastructures. Second, both infrastructures continue to co-exist and there will be a need for a continuous integration and synchronization of data between these two infrastructures. Even though many software developers tend to think that a new system will replace the old system, this is not always the case. A new study could for example investigate the processes involved in facilitating the integration of these two infrastructures.

This project focused on collecting aggregated data to all levels of the health system. Aggregated data in a village is by definition not sensitive as personal data. Although, we have seen that other projects, like RapidSMS in Rwanda, do send personal data by SMS messages. However, it is questionable whether this is a good practice or not. A patient tracker module is currently under development in the DHIS2 intended for tracking HIV patients and pregnant women. There is an interest to extend the patient tracker to also include SMS messaging to be used for patient reminders and registration. In general, the policies and laws regarding privacy and protection of data are not clearly stated in LDC, particularly compared to countries like Norway that have strict regulations for collecting, protection and storage of data. The first ethical dilemma regarding this issue is when a researcher collects data that would not be allowed according to Norwegian policies and laws regarding privacy and data protection. Further, the collection of personal data are often stored in national databases like the DHIS2. When a researcher help the government to collect sensitive information, about for example HIV infections, sexual preferences or pregnancies outside of marriage, these sensitive data can be traced back to the individual. In sum, this raises at least three questions: First and foremost, is it ethical to collect this kind of data? Second, what kind of security issues are present when using SMS infrastructure for the purpose of collecting sensitive data? Third, can data be stored in a proper way in order to restrict access to sensitive data in low resource contexts?

Appendix A

SMS message log

This appendix contain selected incoming SMS messages from the log.

A.1 Project 1: Saving Mothers Giving Life

The messages exemplifies the the observations listed in section 5.5.1 on page 56.

The following messages are incoming messages that have been anonymized. We begin with four messages that serve as examples of the first observation. The first example does not include any codes and values:

```
MCD IHAVE TREAT 9 CHILDREN AND RECOVRED MALARIA ON LAST WEEK,
DISTRICT HAS BULT ASHALWELL OF 4M IN KYARUKUMBYA
```

The second message includes codes and values as well as a summarizing narrative and the name of the VHT worker:

```
Mcd w0 c0. In short no one died. VHT <Name of VHT removed>
```

The third example is a combination of observation 1, 4 and 10, where a message is written without white spaces, zero is written as the small capital letter "o", and at the end of the message there is a summarizing narrative:

```
Mcdtwoco.noanytwomanorinfantwhodieadthisweekthank
```

The fourth example is a combination of observation 1, 2, and 4. The VHT worker first write a large capital "O" instead of zero, then, there is a short narrative containing the same information as the report. Finally, the message ends with the name of the VHT worker:

```
MCD WO CO NO ANY WOMAN OR INFANT DIED LAST WEEK.
From <Name of VHT removed>  VHT.
```

Example five to ten all share the mixing of numbers and characters, and in some cases signs. The fifth message confuses the expression sign with the number one, and the letter "O" with the number zero:

```
MCD C! WO
```

The sixth example confuses the lower case letter “o” with zero:

```
MCD Co Wo
```

The seventh example confuses the latter “m” with the letter “w”, in addition to confuse lower case letter “o” with the number zero:

```
mcd mo co
```

The eighth example has dots as a separator instead of white spaces, and confuses the number zero with the capital letter “O”:

```
MCD.WO.C1
```

The ninth example mixes the white space separator with the hyphen, and the capital letter “O” with the number zero:

```
MCD-CO-WO
```

The tenth example also mixes letter “O” with the number zero. The message ends with the service number 67676:

```
MCD CO WO 6767
```

The eleventh example mixes equal and white space as a separator:

```
Mcd=c0=w0
```

The twelfth example skips the separator between the command and the first code:

```
MCDC 1
```

The thirteenth example includes a narrative and ends with “SEND TO 6767”:

```
MCD W0 C0 WEDIDNT LOOSE AWOMAN OR ACHILD LAST WEEK SEND TO 6767
```

The fifteenth example includes names. It is uncertain whether the names belong to the VHT workers in the village or they could also be names of dead persons:

```
mcd w2 Co V H T <Name> ,<Name>,<Name> .<Name> ,L C I .
<Name of Parish>,PARISH
```

The last example includes a correctly formated message reporting that zero women died last week. The report is followed by a narrative stating that one women died last week:

```
Mcd w0 c0 one woman passed away and non of the children died last week
```

A.2 Project 2: Prevention of Mother to child transmission

The messages exemplifies the the observations listed in section 5.5.2 on page 58. The following messages are incoming messages which have been anonymized. The first example is using the same separator between the command and the first code:

```
pmtct.a.6.b.17.c.0.d.0.e.0.f.0.g.0.h.y.i.y
```

In the second example, the users only put the separator after every value.

```
Pmtct a 5. b 0 .c 0 .d 0. e 1. f 0. g 0. h N. i Y.
```

Appendix B

The software artifact

In this appendix I will present the software artifact which is the result of this project. This software artifact enables the DHIS2 to send and receive messages from SMS messaging service providers by HTTP and SMPP. Further, it enables the DHIS2 to parse the SMS messages and store the values in the DHIS2 database. As illustrated in Figure B.1, the parsing of incoming messages are done asynchronously.

B.1 SMS Messaging Service Providers

Most mobile operators will provide services for sending SMS messages within their networks. However, sending messages to mobile phones connected to any network requires the following: First, one would need a contract with every operator in a country in order to send SMS messages to all networks. Second, the sender system will need to be integrated with the systems of all providers. This could potentially involve multiple protocols. Third, the system must also be able to route the messages to the correct network. These demands makes it preferable to contract a SMS Messaging Service Provider in order to handles this complexity. The SMS Messaging service provider will send the messages to the correct network and handle contracts and protocols for each network operator. SMS messaging service providers are found in most countries, including both Uganda and Rwanda.

SMPP and HTTP are the two main protocols used to communicate with the SMS Messaging Service Providers.

B.1.1 SMPP gateway

SMPP is the protocol used by the telecommunication industry to exchange SMS messages. The main advantage of SMPP is a standard protocol, which makes it easy to configure. The software artifact use the java library called JSMPP. This library currently support SMPP version v3.4. SMPP is usually used for larger scale setups. The provider BulkSMS will for example only give SMPP support to customers who buy more than 5000 SMS messages.

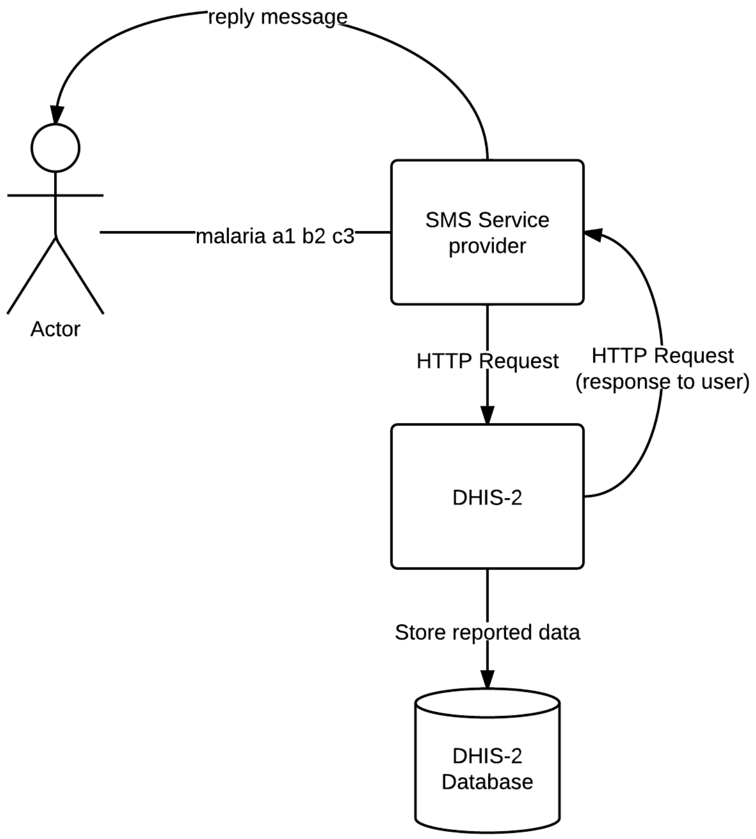


Figure B.1: Example of user input using a SMS message service provider which forwards messages using HTTP to DHIS2

B.1.2 HTTP gateway

Using the HTTP protocol for sending and receiving messages provides the simplest setup. However, the implementations may vary more than the SMPP, because there is no official standard available. Sending and receiving messages is conducted by HTTP requests (POST or GET). As illustrated in Figure B.1, the SMS service provider will perform a HTTP Request to the receiver when a message is sent to the system. Equally, when a system is sending a message it will perform a HTTP Request to the service provider. Because this is no standard, each provider may implement their own variants that use different parameters for the HTTP Requests. One advantage of the HTTP implementation is its stateless design.

B.2 DHIS2 maven projects

DHIS2 source code is organized in more than 40 Maven projects. The projects are organized as a tree structure with projects and sub-projects. This project have contributed to the following maven projects:

- dhis-api
- dhis-services

    (...)

    dhis-service-core

    dhis-service-sms

- dhis-web

    (...)

    dhis-web-sms

    dhis-web-maintenance

      (...)

      dhis-web-maintenance-mobile

The first project "dhis-api" contains the Java interfaces. The second project contains the Hibernate Services ands XML mapping files. The third project "dhis-service-sms" contains implementation services for the Parser, Message Queue and the SMS Gateway. The fourth project "dhis-web-sms" contains the web form for incoming SMS messages. The fifth maven project "dhis-web-maintenance-mobile" contains the web user interface for creating new and configuring existing SMS commands.

B.3 Model

A SMS command is an object containing the configurations for each SMS form. An UML diagram of the SMS command and the corresponding SMS codes can be viewed in Figure B.2. The first property is the name of the command. This is is an unique identifier for the command and is the first word that is written in the SMS message sent to the DHIS2. Second, we have the parser. This property identifies which parser the handler is going to run when receiving a SMS message for a particular SMS command. The data set contains all the data elements that can be used by the command. The fourth property is the codes, which are to be used in the SMS message in order to identify data elements. The SMS code objects contains the key word for the code. The codes is the link to the data element as well as a the category option identifier. Finally, we have the separator which is used to separate the codes and values when parsing the SMS message.

B.4 Services

When the system is configured and running, there are two main concerns for the DHIS2. First, it must receive messages. Second, it has to parse the incoming messages. I have split this into two independent sequences. This is done to avoid crashes due to overload. All incoming messages are first put in a queue and later parsed one by one.

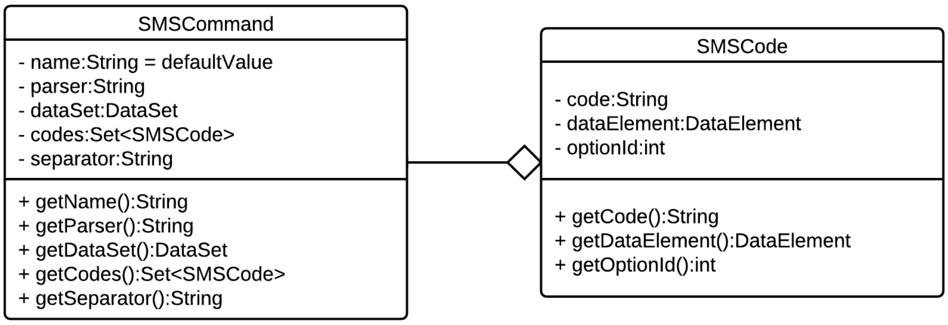


Figure B.2: UML diagram: SMS Command object

B.4.1 Incoming messages

Incoming messages are handled by the incoming SMS service. The service is responsible for two things, storing the message to the DHIS2 database and adding them to the Message Queue. This is shown in sequence diagram in Figure B.3.

B.4.2 Parsing messages

Parsing of incoming messages are done asynchronously by a Message Consumer Thread. This thread is fetching the messages from the Message Queue and calling the Parser Manager, as shown in the sequence diagram in Figure B.4. The Parser Manager will look up which parser to use for a given SMS command and execute the parser. Afterwards, values found in the SMS are stored in the database. Finally, a response SMS is sent to the user.

New parsers can be implemented by extending the IParse interface in the DHIS2 and by adding the implementation to the Parser Manager.

B.5 Web user interfaces

Configuration of the SMS command and SMS Gateway is located under the “Maintainance” menu in the DHIS2 web portal.

B.5.1 Create a new SMS command

The web user interface for adding new SMS commands is presented in Figure B.5. In order to create a new SMS command one must first write a unique name for the command and select a parser. The name is the key word used to identify the SMS command in the SMS message. The parser selects which parser the system is going to use for this SMS command.

B.5.2 Edit SMS command

The web user interface for editing the SMS commands and adding codes is presented in Figure B.7. The configuration screen provides the

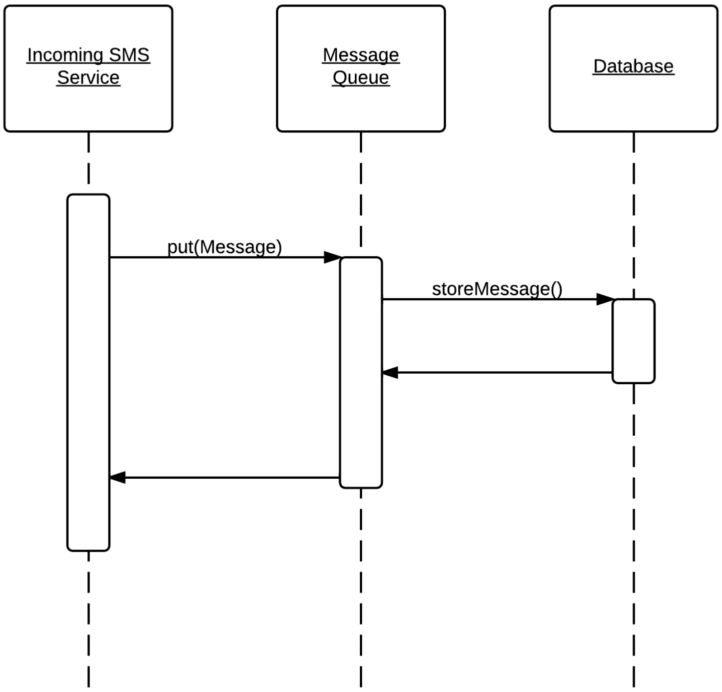


Figure B.3: Sequence diagram for incoming SMS messages

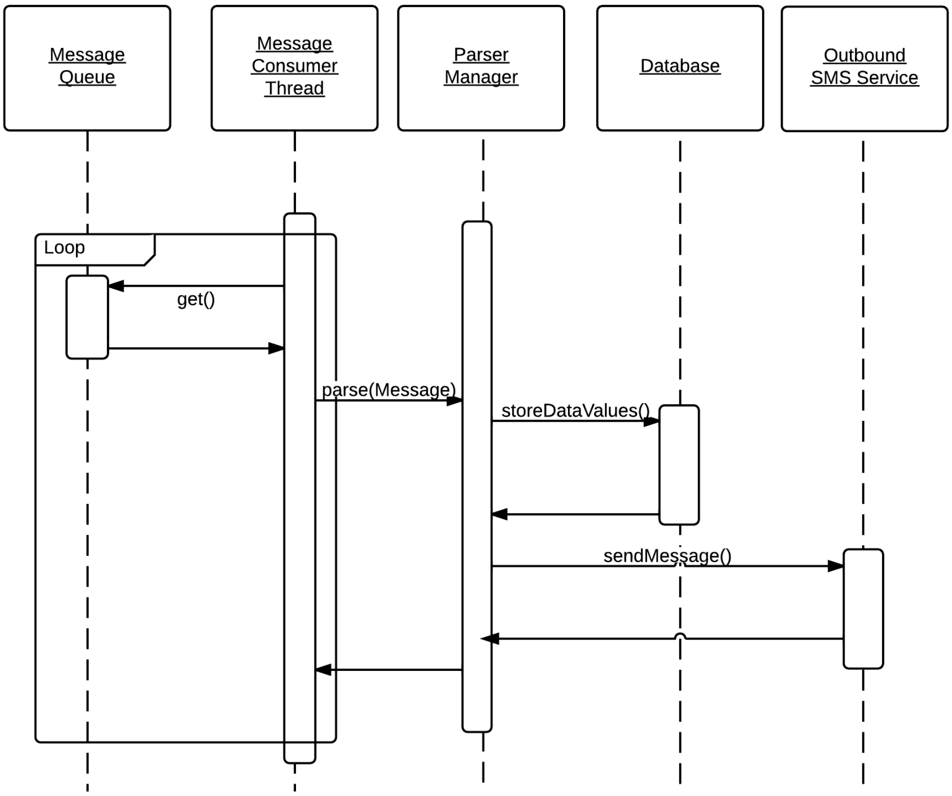


Figure B.4: Sequence digram for parsing of messages from queue

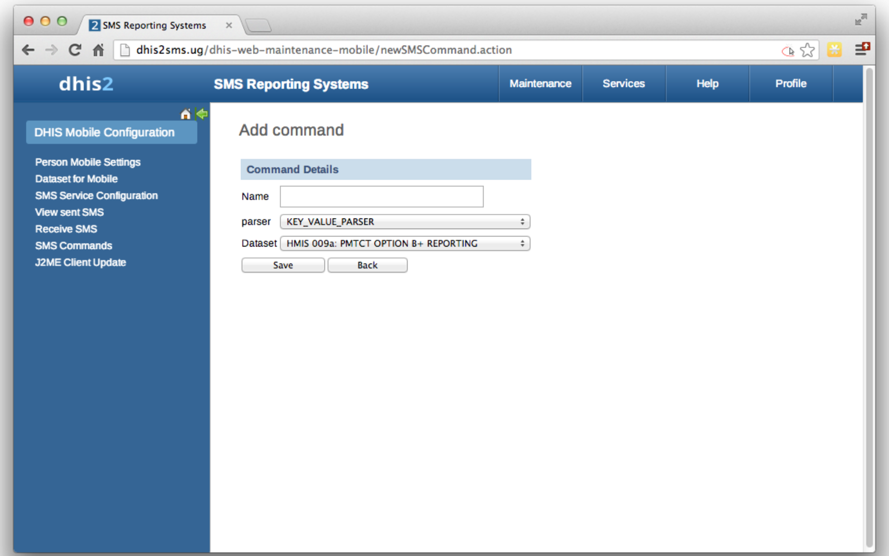


Figure B.5: Web user interface for adding a new SMS command

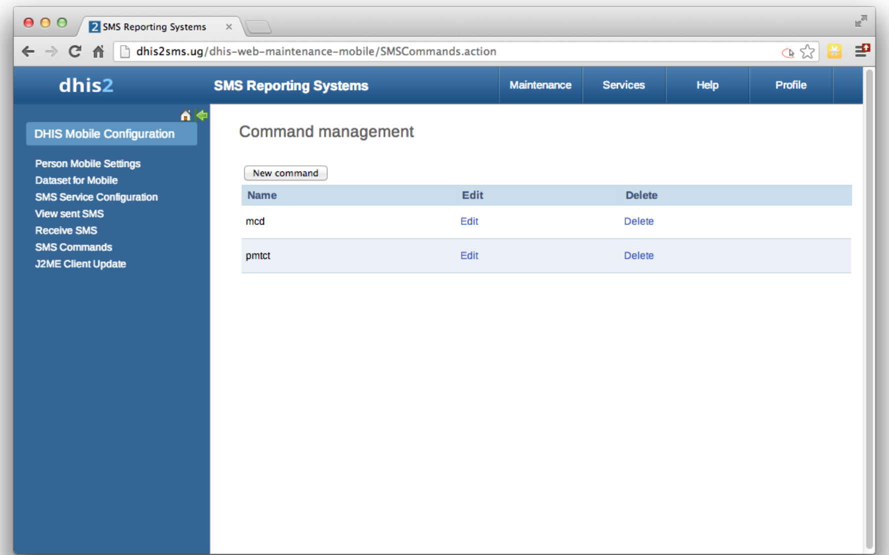


Figure B.6: Web user interface for managing SMS commands

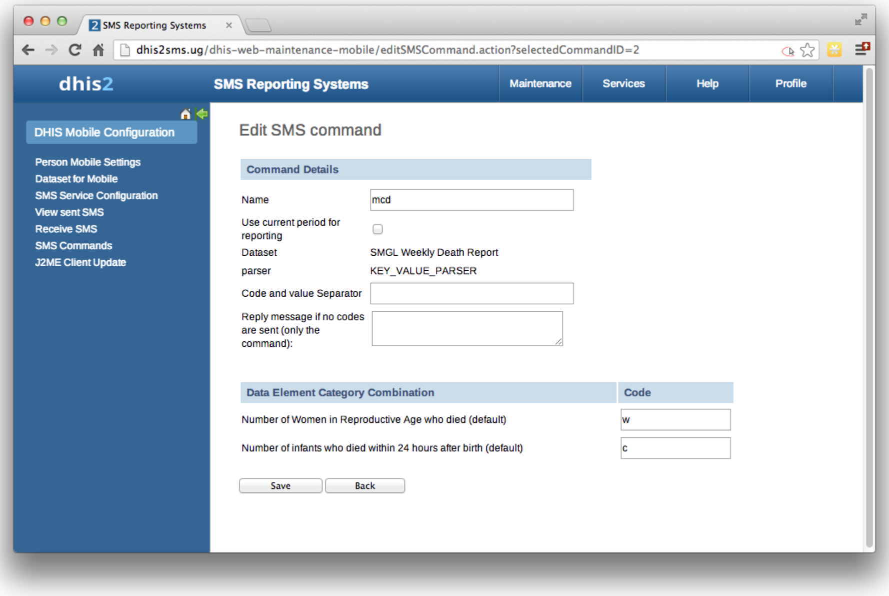


Figure B.7: Web user interface for editing a SMS command

administrator the option to edit modifiable options for the SMS command. Further, it is possible to assign codes to data elements. As shown at the right side of each element there is a input box. In order to add a code for any elements one must write a code in the input box to the right side of the element. The code must be unique for each command. Different SMS commands can use the same code words.

B.6 User input

This section contains some syntax examples for interacting the DHIS2 with SMS messages.

B.6.1 Input format

The user should be able to report data by sending a SMS to a service number using syntax where a command is followed by keys and values, as in the following example:

```
malaria a1 b2 c3
```

This example represents a malaria form with three corresponding data elements. The command is identified by the command word “malaria”. The letters “a”, “b” and “c” represent keys which are followed by a numeric value. The numeric values are stored as data values for the data element in the DHIS2.

The SMS command can have a separator. This will allow the use of numbers in the keys and characters in the values. The above mentioned example with a dot sign as a separator would look like:

```
malaria a.1.b.2.c.3.
```

There are a few requirements for the parsing of these messages:

- Commands should only be one word
- Commands are unique
- Codes should only be one word
- Codes are unique for each command
- Codes and commands contain letters A-Z and numeric values 0-9
- Case insensitive parsing of messages
- Values are whole numbers

B.6.2 Selecting period

Each dataset in the DHIS2 has a reporting period, usually weekly or monthly. For the plain-text SMS solution the previous period is selected automatically if no period is specified. The period can be specified by entering a date on the form *ddMM* directly after the command, as in the following example:

```
malaria 3012 a1 b2 c3
```

If a date in February is specified in January, then the date will be resolved to February in the previous year. Thus, plain-text SMS supports reporting for up to one year back in time.

Use current period as default

If the check-box for “Use current period” is selected in the SMS command edit view, then the default period for reporting will be the current period. You can still write a data to the command to override the reporting period.

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