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Editors
Victor de Boer
Anna Bon
Cheah WaiShiang
Nana Baah Gyan

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Preface

Data sharing usually focuses on centralized and very powerful solutions centred around Web hosted servers and (mobile) clients accessing it. As a direct consequence, the usage of World Wide Web (WWW) and Semantic Web technologies depends on the availability of a Web infrastructure compassing data-centres, high speed reliable Internet connection and modern client devices. The digital divide that is currently widely recognized separates the world into those who have access to Web-based platforms and those who don't. Whilst Linked Data has been designed primarily for using the Web as a platform we should keep everyone in mind when we design platforms and aim at helping to reduce this digital divide. This workshop aimed at achieving this goal through working on three aspects (Infrastructure, Interfaces and Relevancy) around (Linked) Open Data.

Downscale2016 followed the success of previous Downscale workshops DownScale2012 and DownScale2013 and Downscale2014. In this installment of the workshop, we mostly focused on appropriate *infrastructures*. Instead of using large-scale centralised approaches to data management we look at breaking data-centric architectures into smaller components that consume less electricity, be cheaper to own, and more flexible than a "big server" while still mimicking, as a swarm, the features one such big server would provide. As such, the workshop matches ICT for Development (ICT4D) goals with ICT for Solutions (ICT4S) and the goal of the workshop was to promote the dialogue between ICT4S, Semantic Web and ICT4D researchers and practitioners will further each of the research fields.

The workshop attracted 12 participants and we received 4 invited paper contributions, which were presented and discussed in the morning session. These papers describe a issues regarding sustainability of ICT4D approaches, specific downscaled solutions for two ICT4D use cases and a system for distributed publishing and consuming of Linked Data. These four papers are included in these proceedings.The afternoon session was reserved for demonstrations and discussions. An introduction into the Kasadaka platform was given, followed by an in-depth howto on developing voice-based information services using Linked Data. These demonstrations are also represented in these proceedings.

During the discussions afterwards the issue of sustainability was addressed. Different dimensions of sustainability were discussed (technical, economical, social and environmental). The participants agreed that a holistic approach is needed for successful and sustainable ICT4D and that most of these dimensions were indeed present in the four presentations and the design of the Kasadaka platform. There remains a question on how different architectural solutions for services (centralized, decentralized, cloud services) relate to eachother in terms of sustainability and when a choice for one of these is most suited. Discussion then moved towards different technical opportunities for green power supplies, including solar panels.

The Kasadaka Weather Forecast Service

ICT4D Assignment 3

Kim Bosman 2524547
Jari Ferguson 2529692

May 26, 2016

1 Introduction

During trips to Mali and Ghana, the ICT4D department of the VU Amsterdam talked to local villagers through a couple of Living Labs sessions. During these sessions, they could express their needs and wishes for developmental support. These Living Labs resulted in use cases which - once solved - could potentially improve the lives of the villagers drastically. An example of the obtained use cases is receiving more information on animal diseases. If farmers can identify or further specify the illness of an animal, they will be able to estimate the seriousness of the illness. A proper evaluation on the illness could mean the difference between life and death for the animal. A veterinarian can be consulted further, at an earlier stage and the proper care can be provided. Another use case gathered on the field trips to Ghana and Mali concerns weather forecasts. This use case will be further explained in this paper.

1.1 Current situation

In 2010, 66% of Mali's gross domestic product was agriculture[1]. Even though agriculture is extensive, it is comparatively unproductive. For example, in 2010, the sorghum yield in Mali was 1 ton/ha against 4.5 tons/ha in the United States.

One of the main reasons for this difference is the lack of reliable weather information. Accurate information about the near-future weather is very important for farmers. Especially information on incoming rain is very important. Based on rain forecasts, farmers will be able to adjust the watering plans for their crops. If a rainstorm is expected, farmers will not water their crops. Also, the farmers will be able to collect the rain water and safe it for days of drought.

At the moment, weather forecasts for farmers in Mali are sparse. Radio stations either do not broadcast at all, or the broadcast is for a region that is too spread out and thus not specific enough for different regions. Increasing the quality of the forecasts should increase the crop production, since it would prepare the farmers better for the weather that is to come.

[1] http://www.fao.org/fileadmin/templates/mafap/documents/Mali/MALI_Country_Report_EN_Feb2013.pdf

1.1.1 Key idea

In an attempt to help the farmers reach their goal of growing more crops, the idea for the weather service Mali came to mind. The key idea of this prototype is to provide farmers in Mali with an opportunity to call directly to a weather service, in order to obtain weather forecasts for the area of interest. After the initial deployment, the system should work autonomously. The idea is to assist farmers in deciding when to take action regarding sowing and harvesting of crops. However, this service can be useful to many other businesses that are dependent on the weather as well.

1.2 Actors and goals

Table 1: Actors and operations goals

Actors	Operations goals
Farmers and other users depending on weather information	Learn when the weather is suitable for sowing or harvesting
System owner	Provide a working system
Weather Stations	Provide accurate weather information

1.3 Scope

Mali is a country of 1.240.192 km^2, and is home to a population of 14.5 million[2] in 2009. Of the nine districts that can be found in Mali, the three Northern districts Tombouctou, Gao and Kidal only host 10% of these 14.5 million. This is why the decision has been made to focus on the Southern part of Mali for now, which means that the prototype will only feature the remaining six districts. The used districts are marked in figure 1.

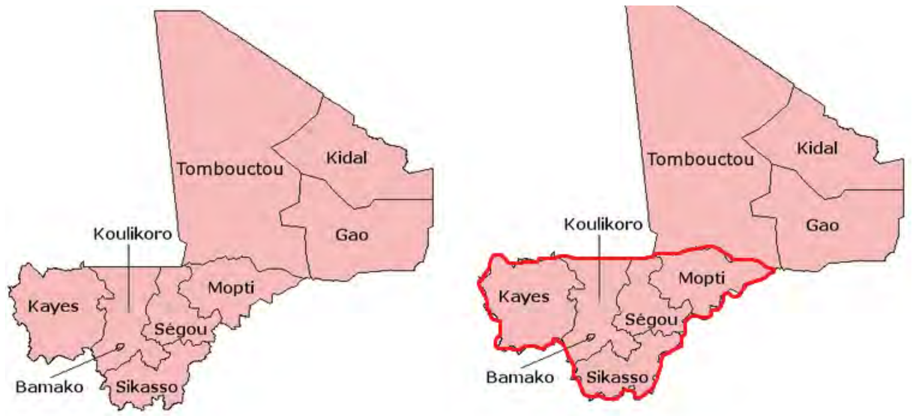

Figure 1: Mali (left) and the used districts (right)

In order to provide the most accurate weather forecast, each district will be represented by four cities. These four cities in turn represent the North, East, South and West of each district. The only exception is Bamako, which is the

[2] http://populationcommunication.com/wp-content/uploads/2014/06/Mali_report.pdf

capital of Mali. The capital represents its own district, and thus all regions of this district as well. The chosen cities for each district can be found in table 2.

1.3.1 Language

Mali is a multilingual country which offers around forty different languages. Since French is the official language of Mali[3], the prototype will feature both French and English voice options. The English language is mostly used for the tests, since none of the developers speak French extensively enough for proper testing.

Table 2: Districts and their cities

District	Kayes	Kolikoro	Sikasso	Ségou	Mopti	Bamako
City	Kayes	Nara	Sikasso	Ségou	Mopti	Bamako
	Kita	Kolokani	Koutiala	Alatona	Boni	
	Béma	Dioïla	Bougouni	Falo	Koro	
	Sitakilly	Karan	Kadianna	San	Dogo	

1.4 Context

Although aimed mainly at farmers, anybody in need of weather forecasts can phone the forecast service. People in need of a weather forecast could include people who plan to travel and would like to check if the weather is expected to be suitable. When users call the system via the number +31 6 83 86 33 17, they can select a region and a place for which they want to hear the forecast. Forecasts are regularly updated and are provided for up to five days including the current day. The system will convey the forecast using basic verbal expressions in multiple languages, so it is accessible for everyone.
If a user calls the service, the first menu that will be provided is the language selection. Then the user selects a region from a list of possible regions. Next, the user selects a place or town closest to her or his location. Following, the users selects for how many days the forecast should be given. The system will obtain the raw weather forecast data from an external service provider and translate the data into verbally expressed weather predictions that the caller can hear in their chosen language. Figure 2 shows an overview of the system. The system can be considered to be successful if it is used by farmers in all the regions and places that the system provides forecasts for. This should be made measurable by analyzing the usage of the system (i.e. when is it used, how often and for which places are the forecasts being asked for). The success of the system also depends on the accuracy of the forecasts - do the forecasts match the weather that occurs? If the predictions are accurate, it should translate into a higher adoption rate. Conversely, if the predictions are often incorrect, the adoption rate can be expected to drop.
Important preconditions are that the system is hosted at a location with the suitable resources. These include a clean and secure environment, with a reliable power supply, and a steady Internet connection for data retrieval. Furthermore, the system will need access to the mobile phone network, in order for end-users

[3] `https://en.wikipedia.org/wiki/Languages_of_Mali`

to be able to call into the system. Lastly, the systems depends on the end-users being aware of the system and having the phone-number that is needed to call the service.

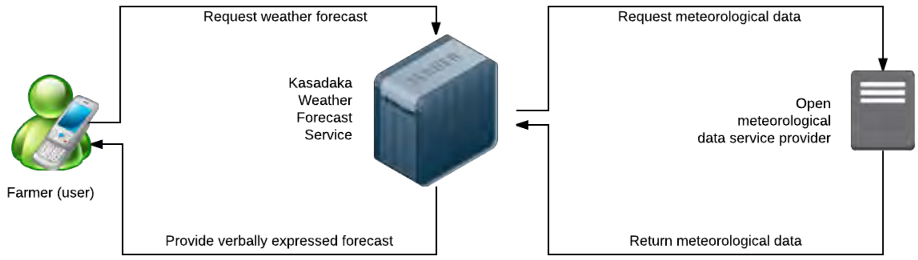

Figure 2: Overview of the system

1.5 Use case scenario script

For end-users, such as farmers, using the intended system is straightforward. The steps involved are as follows:

1. The end-user calls the number of the service
2. The system offers a choice of languages
3. The end-user selects a language
4. The system offers a selection of regions to choose from
5. The end-user selects a region of interest
6. The system offers a selection of places in the chosen regions
7. The end-user selects a place of interest
8. The system offers the user a number of days (up to five) for the forecasts
9. The end-user selects a number of days
10. The system gives a verbal weather forecast for each day the user has selected

1.6 Interaction and communication

Figure 3 shows the activity diagram for the Kasadaka Weather Service system.

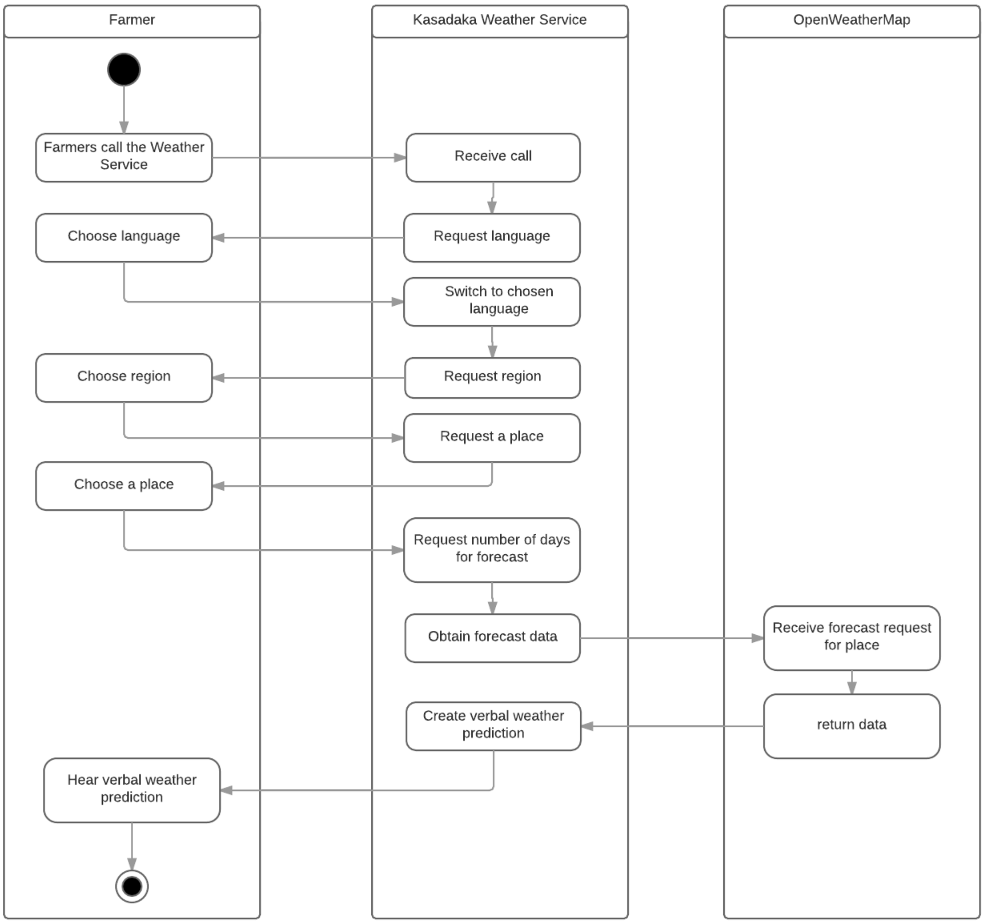

Figure 3: Activity diagram for the Kasadaka Weather Service

1.7 Information concepts

Central to the system is the weather forecast data. This meteorological data is retrieved from OpenWeatherMap (OWM) for individual locations and is stored in numerical format in a local database. Since the number of places for which the system should provide forecasts is larger than the number of possible choices of a phone's keypad, the supported places are split into regions. To make a recognizable distinction between regions, it was decided to use geographically recognized regions.

In order to request forecast data from OWM, it is necessary to provide GPS coordinates of the place in question. For each queried place, OWM returns meteorological data. Of all provided data, the following is considered to be relevant:

- (dt) = time-stamp of the forecast data (to which time does it apply)
- (temp) = predicted temperature for the forecast (given in Kelvin)

- (rain) = predicted rainfall for the forecast (given in millimeters)
- (windspeed) = predicted wind speed for the forecast (given in m/sec)
- (winddirection) = predicted wind direction for the forecast (given in degrees)

This data is summarized in the entity relationship diagram shown in figure 5 on page 14. In order for the data to be meaningful to the end-user, the data needs to be translated into verbal expressions. Also, the granularity of the predictions needs to be considered. OWM provides up to eight prediction per twenty-four hours, but it does not mean that the end-user should be provided with an equal amount of predictions per day. Based on feedback on the second prototype, this has been reduced to two predictions, namely night and day. This means that the eight prediction need to be translated not only into verbal expressions, but they also need to be summarized. Numerical temperature predictions are averaged and translated into *freezing*, *cold*, *warm*, *hot* and *very hot*. Numerical rainfall predictions are averaged and translated into *rain*, *little rain*, *moderate rain* and *intense rainfall*. Wind speed is also averaged and then translated into *light air*, *light breeze*, *gentle breeze*, *breeze*, *fresh breeze*, *strong breeze*, *near gale*, *gale*, *strong gale*, *storm*, *violent storm* and *hurricane*. Wind direction is averaged and translated into *north*, *north-east*, *east*, *south-east*, *south*, *south-west* and *west*.

1.8 Technology infrastructure

Although the system is designed to function autonomously, it is recommended that a system administrator can at least access the system remotely (via the web interface or SSH). Furthermore, due to the limited life expectancy of the storage card (microSD), it is recommended that the system administrator maintains a backup strategy, at least whenever changes have been made to the system. The most basic version of the Kasadaka Weather Service system consists of the following components (hardware and software):

- A RaspberryPI (model 2B or 3B) (hardware)
- A GSM dongle (hardware) with SIM card for voice cards
- Internet access via local network
- Apache HTTPD 2, PHP5 (with SQLite support enabled)
- Asterisk PBX software
- Either a remote computer with access to the system or a screen, mouse and keyboard connected to the system
- A reliable power supply and a UPS system[4] to prevent data-loss

1.9 Cost considerations

In order to properly offer the service, it is important to have an idea of the predicted costs necessary for maintaining the system. We identified maintenance, infrastructure and development costs.

[4] `https://en.wikipedia.org/wiki/Uninterruptible_power_supply`

1.9.1 Infrastructure costs

The hardware used for this prototype consist of the KasaDaka[5]. This is a low-cost, credit card-sized computer which runs on Linux. The next thing needed is a GSM network, which is delivered via a GSM dongle combined with a SIM-card. Adding a local telecom service could either be a prepaid service or a monthly one. Also, an internet connection is needed in order to retrieve the most accurate weather information. If this isn't available the system will make a prediction based on old weather data.
Keeping in mind that the average temperature of Mali lies around the thirty degrees Celsius [6], we have to consider that there might be a need of a storage place, which will bring along additional costs like rent and facilities.

1.9.2 Maintenance and development costs

As of right now, there are no development and maintenance costs since this is a student project. However, if the prototype turns out to be desired it would be interesting to consider continuing with this project. In order to support the maintenance costs, we could ask the users to pay a small amount of money each time they use the service. This will at least partially fund new developments and needed maintenance down the road.

1.9.3 User costs

The system itself will mainly be used by local farmers which need information about the upcoming weather. Right now, the only costs the user will make is the cost of a phone call to the provided number. However, as mentioned before, we might consider asking for a small donation in the future.

1.10 Feasibility and sustainability

Making a weather service is not something new. It's actually something that is pretty well used in Western countries. So the possibilities of designing a weather service for countries like Mali are high enough to make it feasible.
Sustainability is something that has to be thought of as well, since sustainability is important for the earth we live on. Working with the Weather Service will result in a more sustainable use of the available water, both gained from rain and stored for emergencies. By making accurate predictions, farmers do not have to use their water supply if it will rain within a short period of time, and they can even store the rain that is falling to fill their water supplies. This will not only lead to a more efficient way of distributing the water, but it will also lead to a more regular watering system for the crops. The crops will not get too much or too little water anymore, and thus the harvest might increase. This will lead to a worldwide increase of food, which is needed desperately.

[5]https://kasadaka.wordpress.com/hardware/

[6]https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,bamako,Mali

1.11 Key requirements

The key requirements of the system can be divided into three sections, namely: must have, should have and could have.
Must-have:

- Internet access to OpenWeatherMap in order to retrieve forecast data
- Phone-access for end-users to dial into
- Language support for the most-used languages
- A local database for buffering/storing forecast data

Should have:

- Language support for all languages
- A web interface for remotely managing the system
- A report tool to analyze the usage of the system

Could have:

- Configurable translations of numerical data into verbal expressions

2 Contextual issues

One of the biggest contextual issues that had to be conquered during this project was the cultural difference. With cultural differences, we are mostly talking about interpretations. For example, thirty degrees Celsius is hot in the Netherlands, but is this also considered hot in Mali? The same can be asked for rain, four millimeters of rain is not considered a lot in the Netherlands, but it might make a huge difference in Mali. Working on a use case that was provided did not make this issue any easier, since the information is not gathered by the developers. This made it difficult to make a real local-usable prototype, that was understandable by the end users. The feedback provided from Mali was therefore extra helpful, and the prototype got adjusted according to it.
Another contextual issue was the language barrier. Of course the first implementation was in English, but we soon figured out that the main language in Mali isn't English at all. The most spoken language is actually Bambara, but due to time and skill constraints we decided to implement French as the second supporting language. We do believe that this will not satisfy all end users, and that implementing local languages like Bambara are a must.
Finally, the poor infrastructures in Mali were a contextual issue as well. In the Netherlands, everything is taken care of perfectly. In Mali however, the infrastructures are lacking or sometimes not available at all. The Weather Service needs some basic infrastructures to be able to work. Developing and testing the service in the Netherlands meant always testing a working system. Bringing the service to Mali however does not guarantee that the service will actually work. In order to compensate for at least the unsteady internet connections, we decided to incorporate an ”offline mode” which will make predictions based on the weather data that is in the database already if there is no internet connection available.

3 Theoretical background

The prototype introduced in this paper is largely based on research that was already performed by the ICT4D department of the VU Amsterdam. The Kasadaka[7], that is the center of our prototype, is a project that build information acquired by the Web Alliance for Re-greening in Africa (W4RA)[8]. The Kasadaka contains the technical requirements that are context specific. For example, most of the farmers in rural Mali are illiterate. The Kasadaka supports voice-based communication tools to make the information exchange accessible for everyone. Other than that, the Kasadaka is affordable due to the low cost components it consist of, which is ideal for rural areas, in which the infrastructures are not that optimal.
A big inspiration for this prototype was the project RadioMarché[9], which works with both voice-based technology and a web service. Combining these technologies makes the service accessible for literate users, but also for illiterate users. This should be the end goal for every development project, since you want to help as many people as possible with your service.

4 Solution

The solution to the irregular weather forecasts is the Kasadaka Weather Forecast Service. As in any prototype design, some design choices had to be made. The following subsections provide an overview of these decisions and the rationale behind it.

4.1 Design choices

4.1.1 Use Beaufort scale for wind speed

The Beaufort scale for wind speed is internationally accepted and provides verbal expressions for a large range of wind types.

4.1.2 Use compass directions for wind direction

Using the compass directions for wind directions is more natural than using degrees. People will understand these compass directions better than degrees.

4.1.3 Store forecast data in a database

Since OpenWeatherMap only updates the forecast data every three hours, it was considered to be a waste of bandwidth to retrieve the data for each received call. By comparing the time-stamp of the last update with the current time, unnecessary requests to the API can be avoided.

4.1.4 Only retrieve meteorological data when needed

The decision was made to only query the OpenWeatherMap system when the meteorological data is needed. When a call is received, requesting forecasts for

[7]http://kasadaka.com/about.html
[8]http://w4ra.org/
[9]http://w4ra.org/radiomarche-voice-based-market-information-system/

a particular region, the system will first query its local database. If the data does not exist or it is considered to be too old (older than three hours), the system will query OpenWeatherMap first and store the response in the local database. Then it will use this data to provide the forecasts to the caller. This is illustrated in figure 8 on page 22.

4.1.5 Start out with English and French as main languages

Since French is the official main language spoken in Mali, it was decided that this language had to be implemented in the first prototype. However, since none of the developers speak French, it was decided to also implement English for proper testing.

4.1.6 Provide wind and temperature forecasts

The first prototype that was built only provided forecasts for rainfall, as stated in the original use case description for this project. However, it was suggested by Francis Dittoh that the service should provide forecasts for wind and temperature as well. These additional factors are regarded as important by the end-users in Mali.

4.1.7 Using OpenWeatherMap for the source of meteorological data

In order to provide the intended system with weather forecast data, the decision was made to use the freely accessible data provided by OpenWeatherMap. Accessing global forecast data can be done via an API that they provide. Furthermore, the service provides forecasts up to five days, which is also requested in the original use case description. This service was also considered to be suitable, as the API provides data on predicted wind speed, wind directed, rainfall and temperature.

4.1.8 Using SQLite for local storage

For local storage, SQLite[10] was considered to be suitable, as it does not require any additional software installation and is well integrated with PHP. Furthermore, PHP is also well integrated with XML, so it was considered to be very suitable for generating VoiceXML[11] scripts, used by the Asterisk[12] component installed on the Kasadaka platform.

4.1.9 Provide web-based user interface

French is not the only language spoken in Mali. So the decision was made to allow the system to support multiple languages in a user-friendly manner. In the second prototype there was no easy means for doing this. Someone would have to install software in order to make the necessary changes in the local database, determine which additional audio-clips would be needed and upload these in a folder on the server. This limitation was overcome by providing a web-based user interface in which additional languages can be defined and linked to the

[10] `https://www.sqlite.org/`
[11] `https://en.wikipedia.org/wiki/VoiceXML`
[12] `http://www.asterisk.org/`

country that the system serves. Furthermore, the web interface should provide the option to upload the necessary audio-clips into a folder where the system expects to find these.

4.1.10 Supporting multiple countries

The decision was made that the system should not be built around one county only. It should be able to be deployed in multiple countries in a user friendly manner. In order to do this, a web-based interface was created in which countries can be defined. However, it was also decided that a single instance of this system should only support one country at a time. It was considered to be user-unfriendly if the user has to first select a country. Also, it was considered to be more useful if each country would have at least one system of its own. The web-interface provides a means of selecting the country that the system should serve.

4.1.11 Assigning languages to countries

Although the decision was made to support multiple languages, it was recognized that not all languages should be supported by each defined country. Therefore, it should be possible to specify which languages should be supported for which countries.

4.1.12 Web-based interface for specifying regions

It was decided that the system administrator should be able to manage the regions that the system supports. For instance, some regions may require a split into more regions. For the third prototype the decision was made that a user-friendly web interface would be more suitable for this than having to do this directly in the local database.

4.1.13 Web-based interface for specifying places

For the same reason as the previous design decision, it was considered to be useful if the system manager is able to specify places that are part of a supported region. Furthermore, by providing these using an interface, it would reduce the risk of introducing errors into the system.

4.1.14 Using GPS coordinates for specifying places

Because the OpenWeatherMap service does not recognize all the places in the world by name, it was decided that it would be more suitable if the GPS coordinates (latitude and longitude) are used instead. Furthermore, this would make it possible to specify places that do not have a formal name or are too large to be considered as one place.

4.1.15 Provide an export function of the caller history

It was considered to be very useful if the system can provide an overview of the usage. It was decided that the system should register each call made and store the selected country, language, region, place, number of days for the forecast and the time of the call. By allowing the system manager to download this data in a CSV-file, it can be used in, for instance, Excel, to analyze the system usage. It could, for instance, be used to determine which places or regions are most active. Also, it can be used to determine which languages are used most. The data can also be used to determine how much the system is used and if it may need to be scaled. Furthermore, it can also be for determining the expected revenue. It should be noted that this export function does not contain any personal information, such as the caller's phone number.

4.2 Field trip feedback

For the field trip to Mali, a few questions for specified feedback were designed. The feedback received was very helpful, the three main feedback points are further explained below.

- *Report frequency:* Prototype 2 of this system used four forecasts for each day, which included morning, afternoon, evening and night. However, from feedback it was learned that this frequency was too high. It was considered sufficient it the system provides a forecast for night and day only. This was therefore implemented as: night (00:00 - 11:59) and day (12:00 - 23:59). It should be noted that the same amount of meteorological data is used, despite the reduction of granularity.
- *Languages:* The second prototype only supported English and French. However, this would not be adequate for a large section of the target audience. Unfortunately, it was not viable to introduce additional languages at the moment. Instead, the decision was made to provide the system with a user-friendly method of introducing additional languages themselves.
- *Temperature index:* The translation of the temperatures used by OpenWeatherMap into verbal expressions was not considered to be suitable according to local standards. The rules that were used where considered to be very European. Using the feedback provided, a new set of translation rules was created.

5 Implementation

The following two sections describe the end-user interaction with the system and the web interface for managing the system.

5.1 The voice interaction component

The end-user of the system can interact with the system using a basic mobile phone. The user listens to the messages generated by the system and can respond to questions using the keypad on the phone. This kind of interface is provided by Asterisk. It relies on voiceXML scripts to determine how the interaction should take place. These can be static scripts, in which all possibilities are created beforehand. However, because this particular system relies on very dynamic weather data for a large number of different places and potentially for a large number of languages, it was considered to be better if the voiceXML scripts are generated at run-time. In order to generate these scripts, the decision was made to use PHP. VoiceXML, as implemented by Asterisk, allows additional voiceXML scripts to be loaded during execution, using hyperlinks. Furthermore, these hyperlinks allow GET-parameters[13] to be used to pass information to the scripts. As illustrated in figure 8 on page 22, the same PHP-script is called during the interaction between the system and the users. The choices that the end-user makes are passed on in order for the script to determine subsequent actions. When the user initially calls, the system will ask the user to select a language. The sentence of this particular question is expressed in each language. The possible language options are determined by the languages that are assigned to the country that the system is serving. The information is available in the local database. After the user selects a language, the remainder of the interaction will be spoken in the language of choice. In the following menu, the user is greeted. The greeting is personalized to the current time (for instance good morning or good afternoon). The user is then asked to select a region. The possible regions are listed in the database. After the user has selected a region, the user is asked to select a place. This division of regions and places is used in order to minimize the number of choices for each level in the interaction. Lastly, the user is asked to select the number of days for the forecast. The minimum is one day, which represents the current day. The maximum number of days is five. Once the user has provided the right information, the PHP-script can query the internal database for the requested forecast data. The user is then presented with the forecasts for each day. Each day consists of a night and a daytime forecast. After the forecasts have been given, the user is thanked for using the service and informed that the call will end.

[13] https://en.wikipedia.org/wiki/Query_string

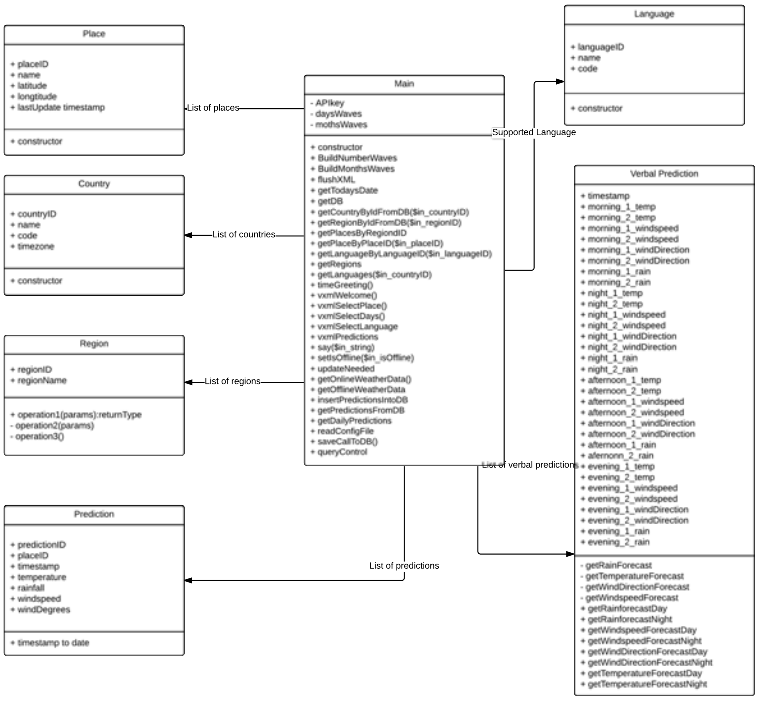

Figure 4: Voice interaction class diagram

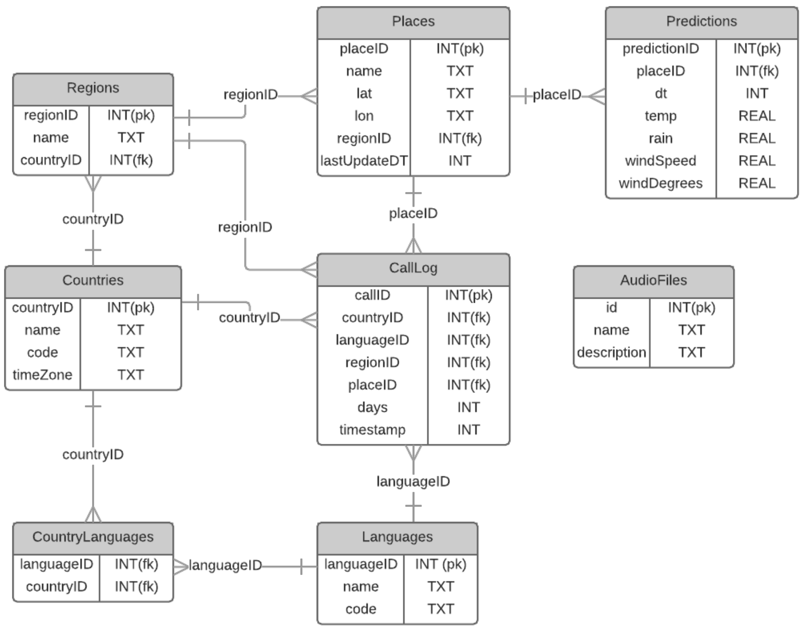

Figure 5: Database ERD

5.2 System Management Interface

Although the second prototype was already constructed to support multiple countries and languages, there was no easy way to implement these. In order to allow a systems administrator or implementer to deploy the system in other countries or to support additional languages, the decision was made to build a web-interface that provides the following functionality:

- Add, modify and delete supported languages, shown in figure 9, page 23
- Add, modify and delete supported countries, shown in figure 10, page 23
- Assign and remove languages to countries, shown in figure 10, page 23
- Add, modify and delete regions, shown in figure 11, page 24
- Add, modify and delete places, shown in figure 12, page 24
- Indicate which audio-clips need to be uploaded in order to support languages, shown in figure 13, page 25
- Provide upload functionality for a selected language and indicate missing files, shown in figure 13, page 25
- Allow the user to change the API key that is used to query OpenWeatherMap, shown in figure 14, page 25
- Allow the user to switch the system from offline mode (demo) to online mode, shown in figure 14, page 25
- Allow the user to choose the operational country (the system only serves one country at a time), shown in figure 14, page 25
- Allow the user to download a CSV-file of the caller history

The web interface was constructed using a single HTML5 script (indicated as index.html) and a single JavaScript script (indicated as kasadaka.js). This script is used to control the interactions of the various components on the web page. Any queries, inserts, updates and deletes for the database are performed by calling PHP-scripts that perform the actions on the server-side. Furthermore, the PHP-scripts are used to create directories on the server, for storing the audio-clips for each language. Also, a PHP-script is used to update the configuration file (config.json) on the server, which is used by the voice interaction component in order to determine the operational mode (online or offline), the operations country and the API key for OpenWeatherMap. Lastly, a PHP-script is used to generate the CSV-file that contains the caller history.

6 Usage scenario

The complete code for the application can be downloaded from
`https://www.dropbox.com/s/n8k5osd11v9ewg1/code.zip?dl=0`.
Also, an image of the system (for Raspberry Pi 2) can be downloaded from
`https://www.dropbox.com/s/lz7k9i2k5j25946/KasadakaV3%28rpi2%29_group_2.zip?dl=0`.

The system can be tested by calling the following phone number:
+31 6 83 86 33 17, and the web interface can be reached via:
`http://www.jsferguson.nl:6009/`

6.1 Example of voice interaction

Next follows an example of the interaction between a caller and the weather information service.
(Spoken in French) Select one for French
(Spoken in English) Select two for English
User presses 2
Good afternoon, this is the weather service for Mali. The date is 19 May.
Please select a region.
Select one for Bamako
Select two for Kayes
Select three for Koulikoro
Select four for Mopti
Select five for Sikasso
User presses 2
Please select a city.
Select one for Kayes
Select two for Kita
Select three for Bema
Select four for Sitakilly
User presses 4
Please select the number of days for the forecast, up to five days.
User presses 1
The weather for 19 May.
In the night it will be warm with light rain with a gentle breeze from the south-west.
In the afternoon it will be hot with no rain with a gentle breeze from the west.
You have reached the end of the forecast.
Thank you for using this service. This call will end now.
The system ends the call

7 Scope and fidelity of the prototype

All the functions that have been listed in the previous sections have been implemented and are fully operational in the third prototype. However, some functions are somewhat limited. These are:

- When a place is added to a region, it is necessary to enter the GPS coordinates manually.
- Audio-files that are uploaded to the system need to be in the correct format, before they can be used. A description of this process is available online[14].

[14] `http://www.voip-info.org/wiki/view/Convert+WAV+audio+files+for+use+in+Asterisk`

- Rules regarding the translation of meteorological data into verbal expressions are hard-coded into prototype 3. Although these rules may satisfy users in Mali, based in their feedback, it may differ from other countries or even regions. An option could be to allow a system manager to use the web interface to create these rules separately for each country. For example, the manager could give a range of values that determine when the temperature is regarded to be hot.
- The voice interaction component does not offer the user to repeat a message or to go back to a previous menu. This could be implemented in the voiceXML script using additional `<goto>` elements.
- The web interface does not restrict the number of regions or places to be added. However, because the user can only interact with single keypad numbers, these numbers should be limited to 9 options at each menu. This can be enforced in the web interface.

8 Plan

This section will describe the future deployment plans and the sustainability of the weather service.

8.1 Deployment

In order for the system to be deployed in a country, the following steps need to be undertaken:

- Determine the number of regions (up to nine) and create these in the system using the web based management tool
- Determine the places for each region (up to nine per region) and determine the GPS coordinates of these places
- Enter the data for each place and for each region
- Determine the languages (up to nine) needed to support the end-users
- Create and upload the audio-clips, using the web based management tool
- Find a suitable location for the system, taking technological requirements into account
- Provide the system with an activated SIM-card for phone access
- Test the system extensively, for each language and each place
- Announce the phone number for accessing the system, for instance via radio broadcasts
- Provide a phone number for gathering feedback with regards to the system

8.2 Sustainability

As described in the costs analysis, keeping the system operational will mean the system will generate costs. As the system can be expected to provide value to the farmers that will use the system, it is necessary to ensure there is a flow of revenue. It will be important to keep track of the costs that are generated and to distinguish fixed and variable costs. For instance, housing and electricity costs can be considered to be fixed costs, as these are independent of how much the system is used. However, variable costs will depend on how often the system is used. For instance, the amount of data that the system will retrieve from OpenWeatherMap will depend on the number of calls retrieved. The system is designed to only refresh forecast data when it is needed so that the amount of data exchanged over the Internet is reduced as much as is possible. By analyzing the call history data, which is provided using the web interface, the number of calls per period can be precisely determined. This data can also be used to determine the costs per call once the amount of calls stabilizes.

Besides determining the actual costs per call, it is also important to learn how much an end user is willing to pay for the service. An important question arises: How can end users pay for using the service? The system does not keep track of who actually called (caller-ID), although it might be possible with the Asterisk component. One approach may be to provide the service through a service number, which could be provided by a commercial telephone company. The end users would then call the service-number, which charges an additional predetermined fee and then automatically routes the call to the actual number of the Kasadaka-system. Such an approach would ensure that revenue is received and the end user only pays for services consumed. This might result in more users, since obliging users to pay a standard fee every month is not possible for a lot of users. Only calling when a forecast is needed is more feasible.

Furthermore, for such an approach, it is necessary to predict the expected amount of calls, in order to calculate the fee. This figure can be adjusted on a periodic basis, as more usage data becomes available. The value flow diagram in figure 6 on page 19 illustrates this.

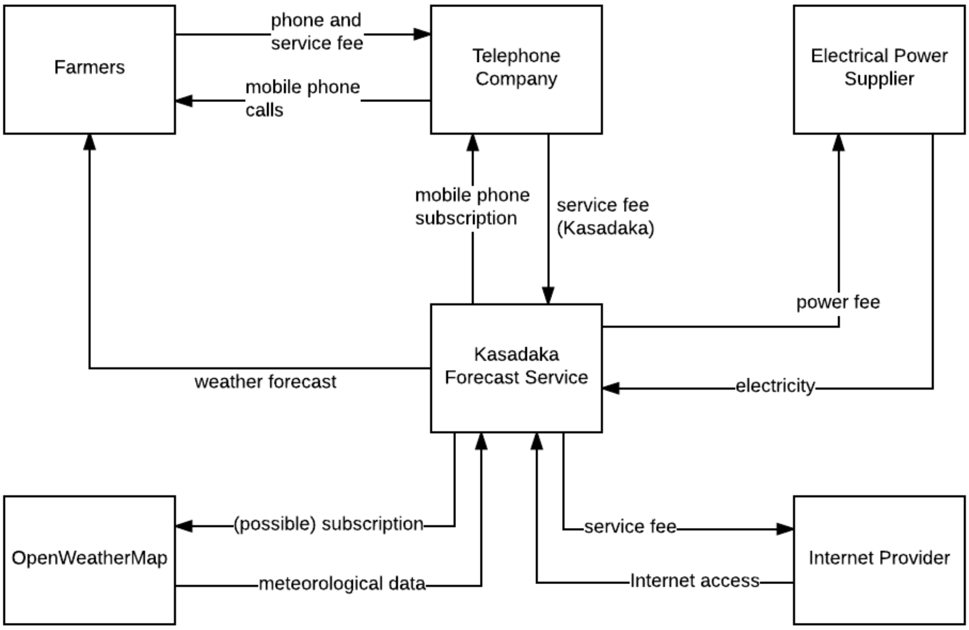

Figure 6: Value Flow Diagram

9 Evaluation

The feedback that was provided by the end users in Mali was very positive. This leads us to believe that the application was well liked. Besides the positive feedback, it is apparent that the application itself works like it should. The caller enters its region and the system will provide the accurate weather forecast as feedback. The current limitations are not a big influence on the end users of the Southern part of Mali, which is currently our most important region of interest.

10 Discussion, Conclusion and Future Work

10.1 Discussion

Besides the limitations mentioned in the "Scope and Fidelity" section, another limitation would be the fact that there are not enough weather stations in Mali, and a lot of other rural countries for that matter, to provide real accurate weather data specified for a small region. The goal should be to work towards adding more weather stations in these regions, especially since a lot of the worlds food is produced there. Accurate weather information is very important and can actually help improve the succession rates of each harvest.

10.2 Conclusion

The overall process of the creation of this prototype was a satisfying one. The prototype features everything that the concept included and even more that was thought of along the way. We hope that the final result will be perceived as useful and desirable for the end users. We believe that the Kasadaka Weather Service can be helpful in the battle against nature, retrieving more crops every harvest.

10.3 Future Work

A next big step would be to add more weather stations in rural areas like Mali or Sub Saharan Ghana. Currently, Tahmo is working on this project for Sub Saharan Ghana[15]. Unfortunately, we cannot influence this process for Mali. For us, the next step will be to work on the current limitations while waiting for more weather stations.
After that, we want to make sure that the implementation of the weather service will be completed for the whole of Mali and in the desired languages as well. After that is completed, we can focus on starting the same service in another country like Ghana.

11 Bibliography and Related literature

Most of the used literature and information used for this project can be found in the footnotes of the pages the information is used at. Other than those information sources, we would like to mention that the course material of ICT4D -both the lectures and the extra reading materials- were used as well.

Extra readings that contribute to the overall knowledge behind this paper:

- The Role of Technology in Environmentally Sustainable Development (1995), Chapter: Pathways to Sustainability. The chapter can be found on: `http://www.nap.edu/read/9236/chapter/5`
- Learning to see: Making value flow from End to End, John Shook (2012). The slides can be found on: `http://www.lean.org/Search/Documents/503.pdf`
- VOICES - VOIce-based Community-cEntric mobile Services for social development, seventh framework programme (2011)
- Communicating agrometeorological information to farming communities, A. Weiss (2000). The paper can be found on: `http://www.sciencedirect.com/science/article/pii/S0168192300001118`

[15]http://tahmo.org/

Figure 7: The logo for the Kasadaka Weather Service Mali

12 Appendix

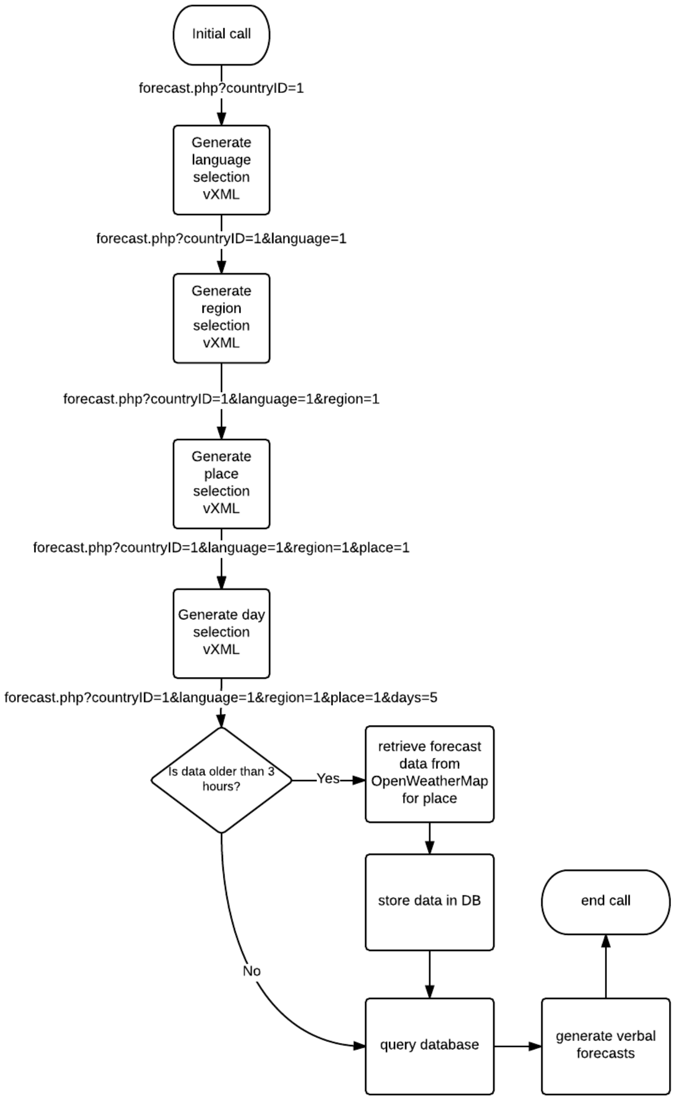

Figure 8: System flowchart

Figure 9: Adding, modifying and deleting languages

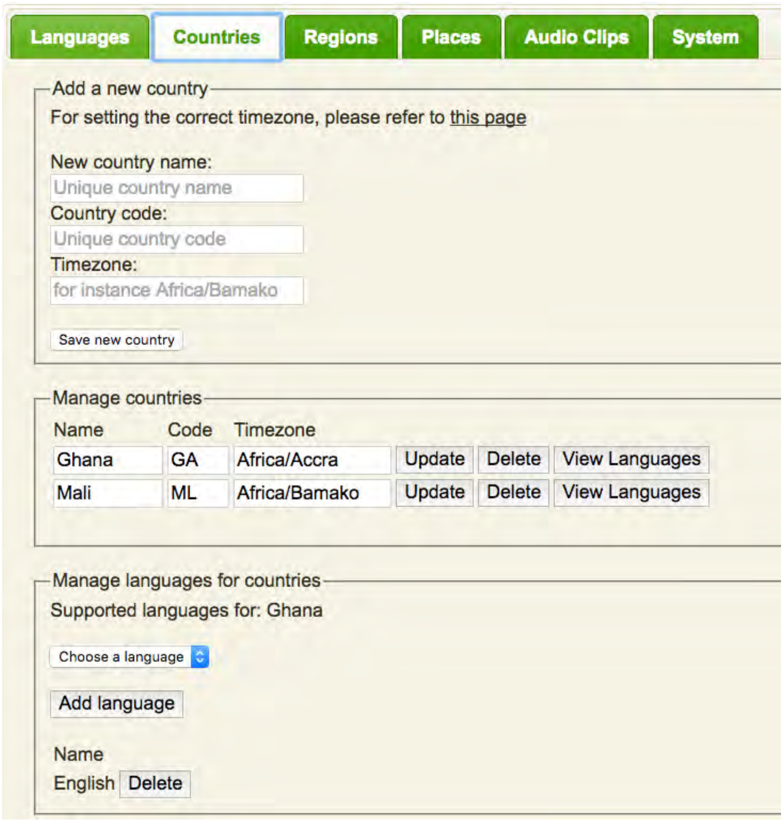

Figure 10: Adding, modifying and deleting countries and assigning languages.

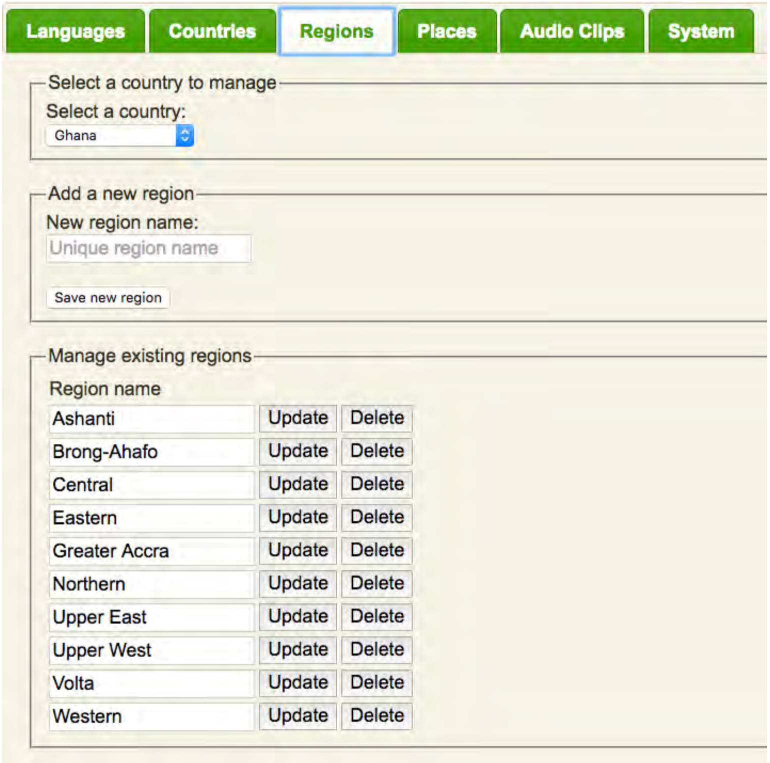

Figure 11: Adding, modifying and deleting regions.

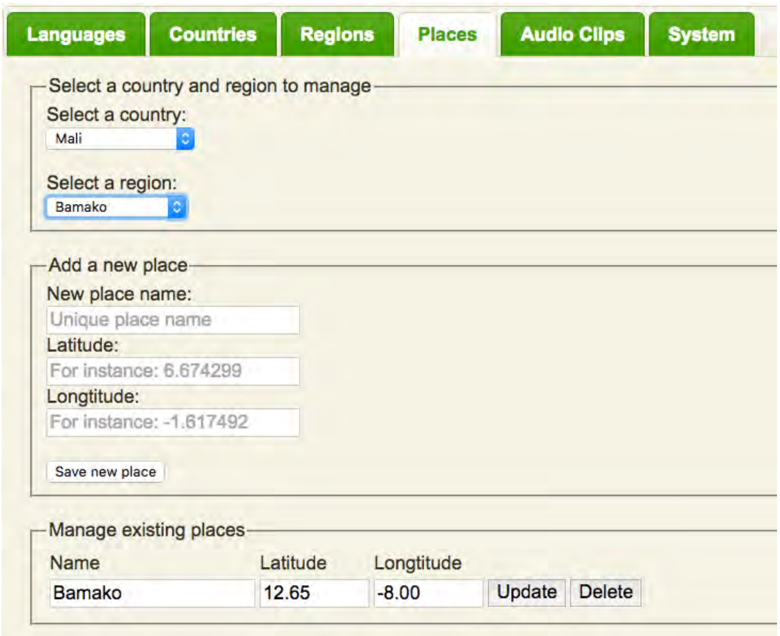

Figure 12: Adding, modifying and deleting places.

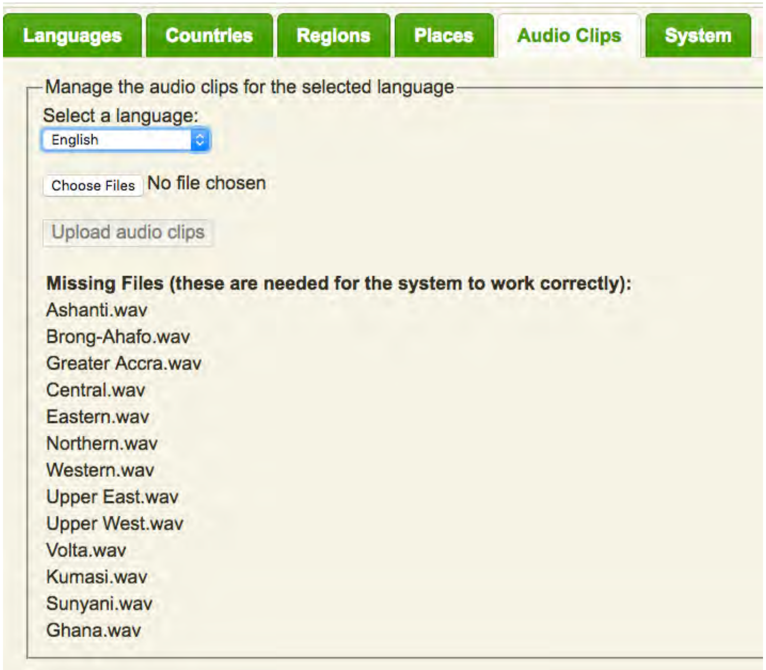

Figure 13: Uploading audio-clips for supported languages.

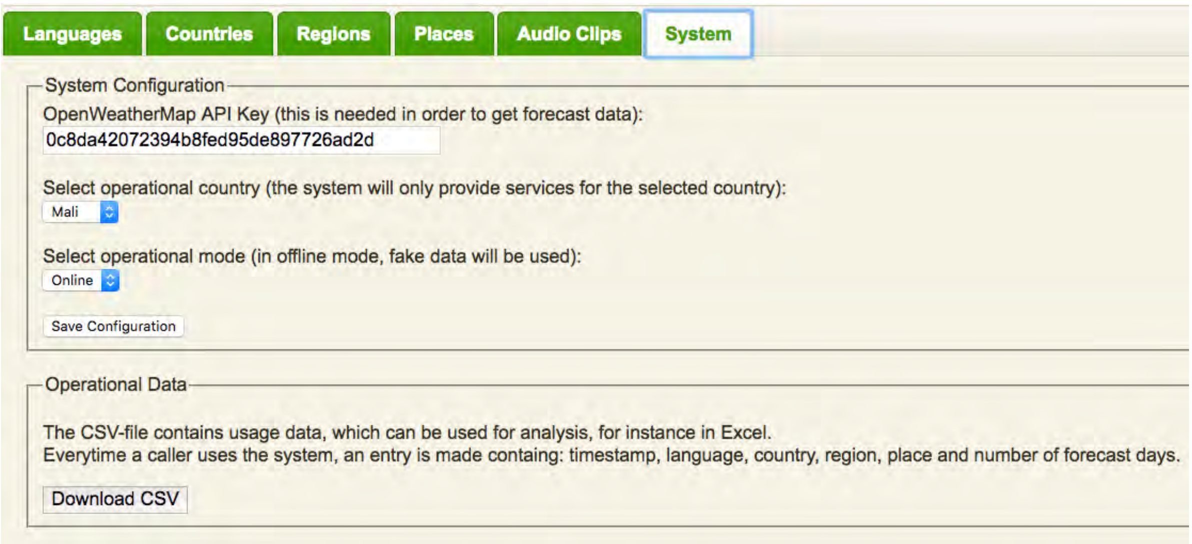

Figure 14: System configuration and downloading caller history data.

The Mali Milk Service 3.0

A voice-based milk selling and farmer networking platform for Tominian Mali

Aske Robenhagen, Bart Aubers

ICT4D
Victor de Boer, Anna Bon, Stefan Schlobach
Vrije Universiteit Amsterdam
The Netherlands
May 2016

1 Introduction

Information and Communications Technology(ICT) has been enormously influential in spurring economic development and the empowerment of people across the world in ways previously impossible. However these benefits have not historically been equally distributed across the world(Sadowsky et al., 2012). The term digital divide(Ho, Smyth, Kam, & Dearden, 2009; Sadowsky et al., 2012) is sometimes used to refer to this gap between a primarily rural and poor population in developing nations and the predominantly urban digitalized population. There have been many projects to help ameliorate this divide, some well-intended, but not successful projects including sending old computers to be used in conditions where they broke down[1] and ended up as landfill[2] to more successful extensions of local technologies in a bottom-up approach like RadioMarché(de Boer et al., 2012). This report outlines the third version of a system developed using a bottom-up approach based on a use case from Mali regarding the need for a local milk selling solution and expanded to help enable empowerment through dairy cooperatives. The use case was created by associates of the Web Alliance for Regreening in Africa (Bon et al., 2013) and extended based on further research outlined in the background and use case sections of this report.

2 Background

Electricity and internet access is sparse in many rural areas (Davis, 1998) across the developing world and particularly in many African nations, but despite of this lack of infrastructure mobile phone usage is high and increasing(Poushter & Oates, 2015). Large parts of Africa have leapfrogged to mobile phones, skipping the land line communication stage seen throughout Europe and North America(Poushter & Oates, 2015). Cell phone ownership has surged in recent years as shown by figure 1 and 2.

This means that despite low internet penetration, there are rich possibilities for mobile based systems in rural Africa. Across rural areas illiteracy remains a big issue(Ho et al., 2009; F. Dittoh, van Aart, & de Boer, 2013) which also precludes use of SMS based systems which in turn can also be prohibitively expensive for locals (Gyan et al., 2013). The multiplicity of local languages across Africa, often with few speakers and small or non-existing textual corpora, means that building systems easily used by locals, requires localization at the micro-level using audio recordings and not through text-to-speech software based on machine learning. Focusing on the local languages has also been argued by some as being a necessary part of sustainable development (Trudell, 2009). Both of these factors make text-based systems suboptimal, giving prominence to voice-based systems (Gyan et al., 2013). An example of a successful voice-based system is RadioMarché(de Boer et al., 2012; Gyan et al., 2013) which extended an existing solution for connecting rural farmers with potential buyers via a phone, web, and radio-based system. Evidence suggests that connecting, in particular women, to informal markets can have a positive impact on food safety by giving them a source of money than can be exchanged for other food stuffs thereby diversifying their food sources and decreasing reliance on a particular food source(Roesel & Grace, 2014). Furthermore, as mentioned during a lecture on the ICT4D course given by Victor de Boer, the lack of access to markets means that many farmers will downsize production to avoid spillage. In Mali, and other countries in the Sahel, this creates a big unused potential for growth in the dairy and associated industries(Kline & Gordon, 2012).

2.1 Gender Issues

Milk production in Mali and elsewhere in Western Africa includes a strong division of labour between the sexes (Roesel & Grace, 2014). In Mali cattle is largely tended and milked by men and male children, often Fulani herders hired by other ethnic groups to tend their cattle(Roesel & Grace, 2014). Women tend and milk

[1] Sandowksy gives the example of Dr. V.K Samaranayake, an important contributor to the standards and development of multilingual websites and the use of the Sinhalese characters in browsers, who described having lots of different hardware shipped to him with no manuals or infrastructure for repairs, leading to them just sitting around in his office in Sri Lanka gathering dust (Sadowsky et al., 2012).

[2] Example given by Stefan Schlobach during the ICT4D symposium on the 6th of April 2016 and restated during the first lecture of the ICT4D course at the VU.

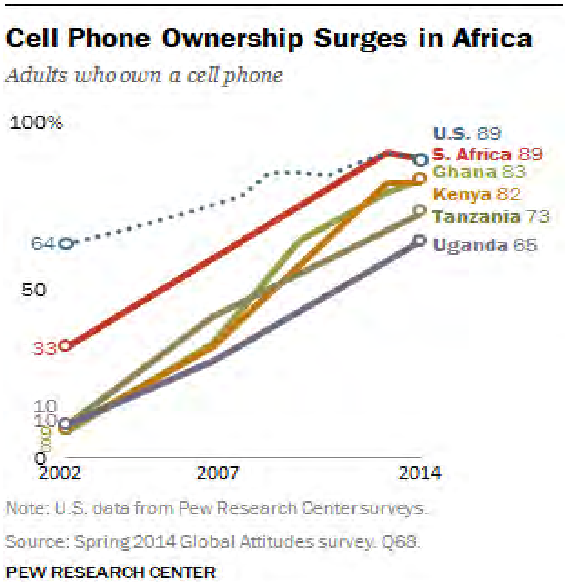

Figure 1: Cell phone ownership based on a sample of 7000 inhabitants based in 7 different African Countries

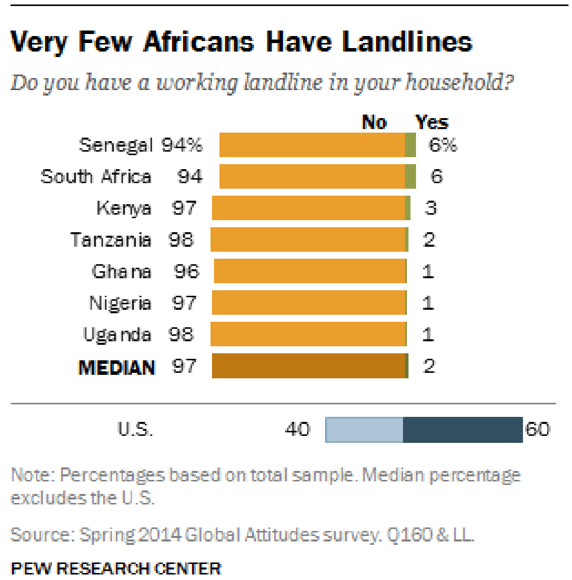

Figure 2: Landline ownership based on a sample of 7000 inhabitants based in 7 different African Countries

smaller ruminants like goats. However, once the cattle has been milked, processing the milk for consumption and sale is largely done by women (Roesel & Grace, 2014). This gender division, which we were unware of when developing the first versions of the Mali Milk Service, has an important impact on the evaluation of the system which will be outlined in the deployment and evaluation section of this paper. A concern about the potential impact of the service on women was also raised at the feedback session in Bamako in response to our submitted question about who could, potentially, be affected negatively by the service(de Boer, 2016). If at present women are responsible for selling the milk and handling the women from those sales, then that system could potentially by disturbed by a service centered around phones, if it is males in the family who own and use the phones. Male members of the family would then be the ones getting phone calls and potentially conducting the sales transactions. This poses a risk to the families, as some studies suggest that cashflows directed towards men and away from women can lead to increased alcohol consumption and associated problems(Obot, 2006). This concern is the reason the Grameen Bank focus their activities and microcredit on women (Yunus, 2016). The backdrop of these gender issues and the potential risk associated with them are an important dimension to consider during evaluation and decisions regarding deployment of any intervention that when plugged in(S. Dittoh, 2016) raises the risk of negatively interfering with an aspect of the existing system.

2.2 Problem

The W4RA use case describing the use for a milk ordering and delivery system for Tominian milk producers in Mali as well as (Chapon, Tourette Diop, & Minta, 2010; Craze, 2012) identified key problems faced by local consumers and milk producers. The key problems identified were:

- Lack of channels to facilitate buying and selling of milk between producers and buyers (Chapon et al., 2010; Craze, 2012)
- Irregular milk production, leading to overproduction in the rainy season and under supply in the dry season (Craze, 2012)

Figure 3: A malinese woman milking a goat (Roesel & Grace, 2014)

The first problem leads to inefficient practices like going door to door to sell milk, often at great effort and time as road conditions remain poor[3]. The second problem results in overproduction in the rainy season and under-supply in the dry season (Craze, 2012) This leads to spoiling of milk parts of the year and the need for expensive imported milk during the dry season. The system outlined in this report is designed for Tomininan Mali, but many of the issues and local factors dealt with also concern people elsewhere in the Sahel(Roesel & Grace, 2014; Gyan et al., 2013; F. Dittoh et al., 2013; Chapon et al., 2010). One of the ways these problems have been successfully overcome in parts of Mali are through cooperatives(Craze, 2012). During the field trip to Mali, participants visited the AB Mini Laterie dairy cooperative, which collects milk from farmers in the surrounding areas(de Boer, 2016). This particular coop cover 60 farmers in approximately 10 villages with a milk-collector per village who contacts farmers via phone. Their central distribution centre will pasteurise the milk which postpones spoiling by around 4 days. From the centre the milk is sold in 1/2 and 1 litre bags, or in bulk for the market(de Boer, 2016). The cooperative is popular and successful, but nevertheless some problems arise:

- Milk collectors are not always quick enough to retrieve the milk, leading it to spoil.
- The communication tends to be unreliable and occasionally cause issues between coops and farmers/collectors.

[3]The long duration of even short journeys was discussed during an informal conversation with Victor de Boer on the 26/05/2015

Figure 4: A Fulani man milking a cow near Mopti, Mali (Sultan, 2014).

The proposed system is called the Mali Milk service (m-Milk) and is a system designed to help with the problems outlines above, both where cooperatives exist and in areas where there are no cooperatives. The system is designed to help local milk producers connect with buyers and help farmers organize pooling of milk and transport to a dairy producer when there is excess production in areas with no cooperatives. In addition to this it is also intended as a service to help connect farmers and lay the groundwork for getting organized into cooperatives and support the work of existing cooperatives if they are already in place. Finally the system is intended as an aid to strengthen the networks between people in rural Mali to enable better knowledge sharing as stated in (Akkermans et al., 2011) and thereby use ICT as tool for empowerment. The use case and more information on the system will be presented below.

3 Use Case Description

3.0.1 Name

The use case name is m-Milk, which is a reference to the mobile usage of the milk buying and selling process in Mali.

3.0.2 Summary of the key idea

The business idea of the m-Milk application is creating a better and more efficient way for Malinese farmers to sell their milk to a broader target audience. If a farmer does not know where to sell, then travelling to the next village and going door to door is the only way to find buyers. Distances and poor road conditions make this strategy both time-consuming and potentially wasteful, if the milk spoils before a buyer has been found. Instead the m-Milk service provides a mobile-based milk selling platform, where a farmer can call in and leave a message about available milk. Potential buyers can call in, hear messages left by farmers, and get the contact information of the farmer with milk for sale. To get a more financially durable service and potentially start a cooperative, the farmers can also leave messages expressing interest in cooperating with other farmers and potentially information that might be relevant to other farmers. If there is a cooperative in the area, like the AB Mini Laterie, then that coop can use the service to share information about their coop with farmers who have not joined yet. If the system is installed centrally at the coop and they have a computer, like the AB Mini Laterie (de Boer, 2016), then they can use a browser interface, that requires no internet, to get an overview of the messages received that day and estimate how much milk they can expect from the different villages and prepare and organize efficient transport if needed.

3.0.3 Actors and goals

The main actors are the farmers and potential buyers. Both of them need to get in touch when the milk is available. The goal of the farmers is to sell the milk, and the goal of the buyer is to buy the milk from the farmer. The goal for each is to make that transaction as efficient as possible. For a cooperative the goal is to reach more farmers and collect and sell the milk as efficiently as possible. The Kasadaka is also considered an actor, considering it is influencing the system. The goal of the Kasadaka is to connect the farmer and the buyers. In the deploymen section, a long-term plan for implementing the m-Milk service is presented which require the collaboration of one or more NGOs. The goal of these organizations will be measurably positive outcomes for farmers and locals relative to the NGO's investment and opportunity costs.

3.0.4 Context and scope

The interaction of the buyer and seller will be facilitated via the voice-based system, though the deal will be made between the two actors. The m-Milk application only facilitates in the connecting of both actors.
As mentioned in the background section, milk production from cattle in Mali has a strong gender dimension. Plugging in the m-Milk systems, in Dittoh's sense of plugging in interventions to an existing system (Dietz et al., 2013; S. Dittoh, 2016) could potentially upset the existing system in undesirable ways. Concerns were also raised at the feedback session in Mali that where women previously handled the sale and money from milk sales, a phone based system could make the man handle that now (de Boer, 2016). Potentially this increases risk that the men will spend the money on alcohol leading to diminished resources and food security for the the family as a whole (Obot, 2006). Being aware of this potential risk is a central part of evaluating the m-Milk service on the ground and one that should rapidly lead to changes to the system, if it turns out to be a problem.
The m-Milk system, like any system dealing with a perishable product like milk, also faces a practical boundary: spoiling of the milk. Farmers cannot travel very efficiently due to the poor infrastructure and therefore cannot transport milk to places far from their location.

3.0.5 Use case scenario script, interaction, and communication

The interaction model is visible in Table 1.

3.0.6 Information concepts

The following paragraphs will elaborate further on the information concepts of the m-Milk service.

3.0.7 Technology infrastructure

The infrastructure for the m-Milk project is already existant. In the first phase of the project to test if the service offers sufficient benefits to justify further deployment, the service will be free. In the next phase, subject to positive evaluation, the farmers will receive a micro loan for the KasaDaka and dongle. The m-Milk is compatible with the technology landscape of rural Mali, and only require users to have a basic

Buying/selling		
Actor 1	**Interaction**	**Actor 2**
Farmer	Calls	KasaDaka
Potential buyer	Calls	KasaDaka
Potential buyer	Calls	Farmer
Co-op		
Actor 1	**Interaction**	**Actor 2**
Farmer	Calls	KasaDaka
Other farmer	Calls	Kasadaka
Farmer	Calls	Other farmer

Table 1: Interaction model

mobile phone in order to call the KasaDaka. At existing cooperatives with a computer, i.g. AB Mini Laterie (de Boer, 2016), the existing hardware can be connected to the Kasadaka, with or without internet, allowing them to see all messages received with time and language codes. These messages can then be played as desired to get an overview of the available milk that day.

3.0.8 Cost considerations

The KasaDaka is a low-cost system, which does not require a lot of electricity. To reduce the buy-in price for locals, the KasaDakas are intented to be supplied via a microloan scheme from an NGO allowing the farmers to pay a little bit at a time. This aspect is outlined further in the deployment section of this paper. The operational costs include electricity costs and call costs for the farmers and buyers.

3.0.9 Feasibility and sustainability

The project, subjects to field studies, is potentially feasible as a stand-alone project, if issues like the system dropping calls are resolved(de Boer, 2016). Development of m-Milk beyond the current version should happen in an iterative, agile, process in close collaboration with local actors as far as it is feasible and the local conditions allow it[4]. This collaboration should be done to build for the local context and should include user studies to ensure that all aspects of the service is user friendly and acceptable in the local context (Dietz et al., 2013; S. Dittoh, 2016). As a prototype m-Milk should be rolled out and work as a standalone service, but for full deployment the intention is to package it is as part of a value bundle(Annor, 2016) to shift the balance of benefit vs cost and help realize what Stefan Schlobach at the ICT4D symposium referred to as the real value of the web - the suite of services built on top of that infrastructure(Schlobach, 2016). Feasibility will increase when the service is combined with other packages and services, such as for example a weather service. Over time, through repayments, the services and hardware will be wholly owned by farmers. The initial buy-in of making a commitment to a microloan and acquiring the system is intended to ensure uptake and motivate use with the secondary objective of making expansion more economically feasible. By creating a co-ownership with the farmers, it is also hoped that the equipment is maintained with care. In an ideal situation this project will break even over time.

3.0.10 Key requirements

The key requirements are described as a means of the MoSCoW model (van Vliet, 2008). These requirements show that the system benefits from stable conditions in the environment such as phone reception. The KasaDaka system has the advantage that it is cheap and therefore easy to deploy on several places. This means that the service will require servers far from the usage of the service.

[4]Hester Stubbe in her guest lecture on the ICT4D course explained the difficulties in access and time required to build relationship with local influencers during the TNO's serious game project in Sudan(Stubbe, 2016)

Must have

- A simple IVR/UX for the end users
- Good instruction on use of application for end users
- Local language settings for the end users
- Be easy to localize by adding new languages

Should have

- A clear IVR/UX for the users
- Low call drop rates
- An expansion with other products and services

Could have

- Web interface for co-operations
- A speech-to-text interpreter for the recorded messages

Won't have

- An internet portal
- Complicated and delicate hardware, which are hard to maintain in rural Africa

4 Financial model

The Kasadaka is a low cost piece of hardware, and should reduce the costs compared to expensive hardware setups in western societies. Nonetheless a starting budget is required, so public/private funding is necessary. To make the Mali Milk Service more (financially) sustainable, hardware purchases and maintenance beyond the trial phase is intended via a micro credit model. Having the farmers buy-in as a group via a micro loan helps ensuring cooperation from local farmers to develop the service provided and get uptake. The farmers will be provided the Kasadaka system as a loan and pay it off as a cooperative a little bit at a time. By creating a sense of ownership the farmers, they will be more cautious with the hardware and potentially might be more driven to develop the system further. This makes the farmer the end-user and end-customer. To prevent downtime, backups and spare Kasadakas are desirable, but subject to budget constraints. In order to provide a good service platform, a maintenance scheme with an NGO or a local university is necessary. The primary stakeholders of this project are:

- Farmers
- Potential buyers
- NGO or government
- Cell phone providers

The value exchange is shown in figure 5 and shows the relationships between stakeholders. The NGO provides a micro loan for the purchase of the technical infrastructure. Farmers can pay off the loan slowly, when profits are rising due to the m-Milk application. The farmers and potential buyers will need to pay small fees to cell phone providers for their calls made for the applications. Milk is exchanged for money by the farmer and buyer, and this completes the value exchanges.

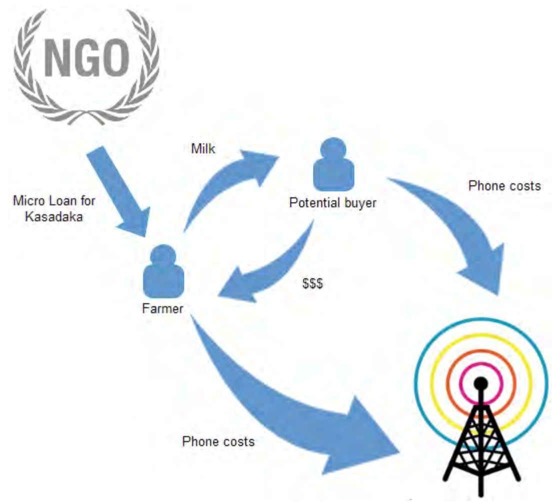

Figure 5: Value exchange model

5 System Overview

A call flow diagram can be seen in figure 11 in the appendix.

5.1 Design Choices

The W4RA use case suggested the need for a buyer-driven ordering system, but in order to help solve the problem of production fluctuations, the Mali Milk Service is designed as a seller-driven platform for milk producers to offer their products to potential buyers. This approach has been kept in version 3. By doing this, it is possible for either the farmers themselves, or potentially a local business, to get information about the local availability of excess milk and organize pooling and transport of the milk to a dairy processing facility or market in areas where there are no cooperatives. This could also include pooling the milk and having it turned into milk powder, which could offer an alternative to expensive imported milk powder in the dry season. A solution successfully implemented through co-ops elsewhere in Mali(Craze, 2012). The seller-driven platform also makes it easier to implement for existing cooperatives as it can help their activities and potentially be a sensible investment for them.

6 Prototype Fidelity

By creating a simple solution for the use case, the m-Milk service provides a low cost option for the milk farmers in rural Mali. By expanding the potential buying community, the farmers can sell their milk more effectively when the cows produce excess milk. To make sure that all farmers have equal opportunities, only one message per farmer is allowed. At the moment the system is not checking for this constraint. But this feature is recommended in order to create a system which is simple and easy to use for the buyers. To deal with language barriers the menus need to be translated and recorded in the local languages and not just French and English as in the current version, so that the users will be able to use the system regardless of mother tongue. If the service proves a success, m-Milk might be expanded to other regions as well as other products. To make sure that buyers only hear messages from farmers in their area a location menu could be added at the start of the call. Callers could then pick their region and then use the same call flow as depicted in Figure 4 in the appendix. The present version does not have this option. At present there remains an unresolved issue regarding recording messages on the Kasadaka. The issue is caused by Asterisk changing

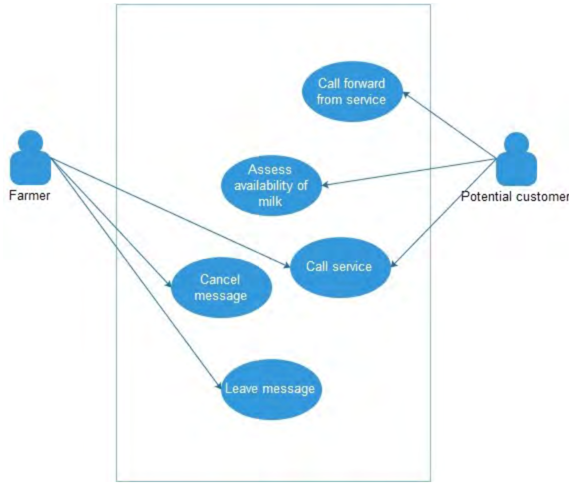

Figure 6: User interaction diagram

the format of GET and POST requests from the VXML record tag when using the submit next tag to send the request, resulting in a incorrect temporary file location being sent instead of the actual message. If it turns out that farmers quickly find a buyer and then receive a lot of phone calls they have to turn down, including an option for farmers to delete their messages as show in 6 could be a sensible addition to the system which it does not include in the present version.

6.0.1 UX Design

In response to feedback on version 1 and 2 of the m-Milk service and several phases of iteratively improving the Mali Milk Service UX design, following the guidelines set out in (Gottesdiener, 2003), several design choices were made. At each step of the call no more than three options are presented to the users, in line with the limits of human working memory(Cowan, 2005, 2001). Barge-in is allowed at each call step as the system is meant to be used often by the same people; who after a while will know their way around the system and might be interested in quickly leaving a message. This reduces the call time by skipping the instructions. This should help them save time and phone credit. The main menu, which is where the caller will first end up, will welcome the caller in all the available languages and then give options like "Press 1 for English", "Press 2 for French" where each option is given in that particular language. This is done to help the user find out how to get to their particular language path, where they will then only hear messages in the chosen language for the remainder of the call. This includes only hearing the messages recorded by callers who chose the same language as they chose. Milk offer messages are stored for 5 days, because milk is a perishable product and excess milk is likely to come in small amounts, so this helps prevent buyers calling farmers in vain. The message overview available if a coop has a computer is kept in very simple html to be backwards compatible with older hardware and software.

7 Stake Holders

The stakeholders of this use case are the farmers, buyers, and a facilitating organisation who can help cover the initial cost of setting up the system and plugging in the system. When the farmers see benefits from the system and are able, and want to, pay for the ongoing costs of the system between themselves, this financial support can be lowered. The system is intended to be implemented similar to micro loans, whereby seed money is given to a group of people, though here with the caveat that the organization will cover the costs if the farmers feel they see no benefit and do not wish to pursue the system further.

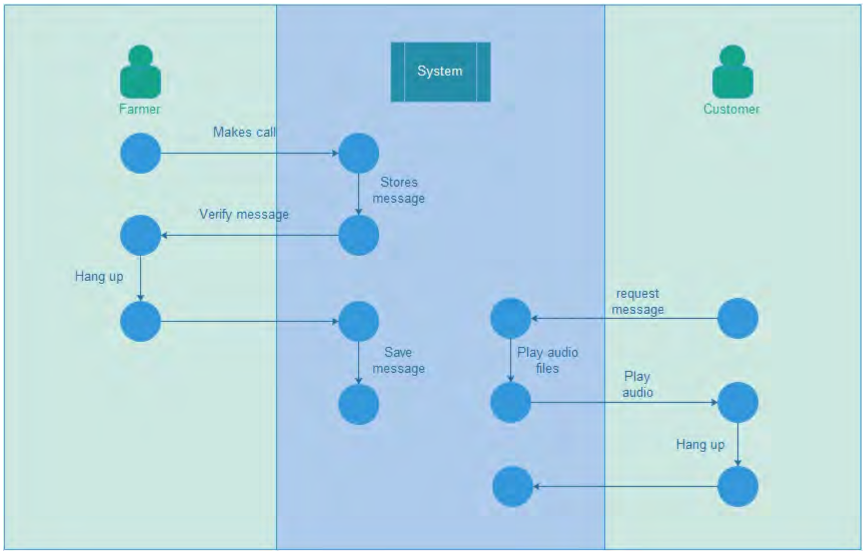

Figure 7: Activity diagram

8 System Architecture

The Mali Milk Serice will run on the Kasadaka system, which is a low-cost Raspberry pi based system(*Kasadaka Description*, 2016), which runs on the Debian Raspbian(*Debian raspbian*, 2016). In order to make the Raspberry accept phone calls, a dongle with a telephone SIM card is used. Using Asterisk, an open source framework (*Asterisk Description*, 2016) which turns the raspberry into a communication service, a communication hub for inbound and outbound calls is created.

9 Architecture

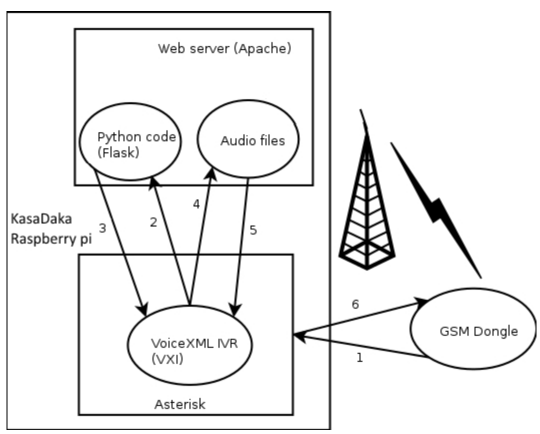

Figure 8: Architecture of the system

To connect the incoming call through the dongle with the VXML files an Asterisk service runs a VXML(*OpenVXI Description*, 2016) interpreter and a locally running Flask (`http://flask.pocoo.org/`) server will respond and render the Mali Milk Service VXML files and html for the computer interface with

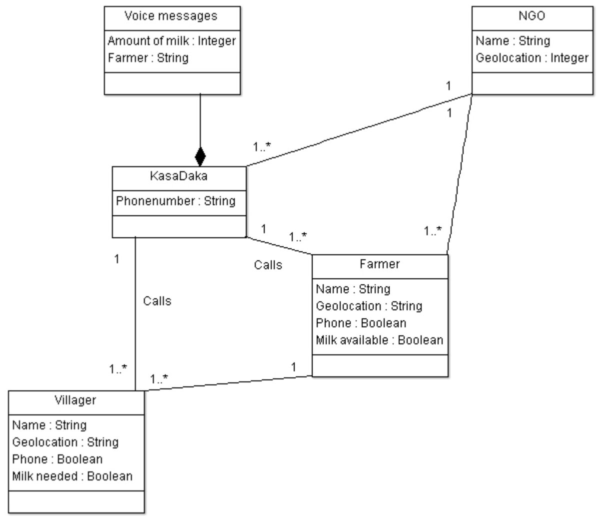

Figure 9: UML Class diagram of system

their corresponding audio files.

10 Data Model

The main actors of the system are

- Farmers
- Villagers
- KasaDaka

Figure 9 shows the Class diagram with all the classes and their interactions. The activity diagram is shown in Figure 7. These diagrams gives a visual representation of all the actors and the interaction they have. The voice messages are shown as a separate class, because they are saved entities on the KasaDaka system and store information which is used by farmers and villagers. The goal of the system is to inform the actors and increase connectivity in a local environment. The service is currently not collecting nor connecting to open data, but a connection with a geolocation database could be useful if caller locations could be accurately used. Then this information could be quickly rendered on a map using D3.js to have the computer interface at the coop include a visual representation of all farmers with available milk on a given day - potentially aiding in transport planning. In the future information about locations and amount of milk available could be extracted, saved in a SPRQL database and submitted to a central database via sms or collected and pooled ready for research into milk production in Mali. Local NGO's, entrepreneurs, and goverment agencies could benefit from this data, and get valuable information on where dairy processing facilities are most needed. The service is kept simple in terms of implementation, localization, and eventual system maintenance by people on the ground who might not have a background in computer science. If the service is successful on the ground in Mali, it can be expanded by structuring the incoming messages and storing the data in a database, using a Resource Description Framework (RDF). In order to use the data in the messages recorded, a speech-to-text interpreter needs to be installed. This enables the application to also get information on the quantities of milk produced and bought/sold. This requires more development of the application and was unfortunately not possible due to the limited timescale of the project. If such a semantic network is deployed it will ensure a transparent data source which can be copied for other purposes. More information on this expansion is given in the future works section.

11 Installation Guide

The print-ready installation guide is found in Figure 14 of the Appendix.

12 Demonstration scenario

12.1 Individual farmer in a region without a cooperative

Adama, a farmer, has cows which sometimes produce enough milk for Adama to sell some of it. Walking to potential buyers is a time and energy consuming activity without a guarantee of selling any milk. This is where the m-Milk Service is useful. The service can help buyers contact Adama if he calls the service and leaves a message with his phone number and how much milk he has for sale. Now customers knows that Adama has milk and can call him to arrange delivery. Adama can go directly to the interested buyer knowing that he is not going in vain. The Mali Milk Service can also help Adama to collaborate with other farmers. Adama can call up and record his own message saying he is interested in getting in contact with other farmers or he can listen to the messages of other farmers. This way they can organize transport to a milk powder factory or the market in a bigger town when they have a lot of milk available. The milk messages of Adama will be deleted after 2 days, whilst messages for other farmers will be available for a month.

12.2 Existing Cooperative

The Mopti Laterie receives milk from several farmers from different villages. These farmers are contacted by collectors who bring the milk from several farmers to the pasteurizing factory. This process needs to be done within 4 hours. The communication with the collectors/farmers and the Laterie happens on a daily basis via phone, though this process is not always reliable. When the milk is pasteurised, it is prepacked in 1/2 and 1 liter bags and sold to villagers. The milk are also sold in bulk on a local or bigger market. The m-Milk service could benefit the Laterie, as having access to the recorded message either via phone or the interface makes it easier to get an overview of how much milk is available and can help coordinate milk collection. For the farmers connected with the Laterie, the efficiency improvements could lead to less errors around milk collection and less spillage.

13 Gender Issues and Actor Analysis

Evidence suggest that alcohol problems are a factor amongst Malinese men (Obot, 2006). This is an issue which must be taken into account. If the m-Milk application results in a shift of cash flows, resulting in money for the sale of milk previously went through the hands of women, are now flowing to the men this could exacerbate alcohol related problems and impact food stability(Obot, 2006; Roesel & Grace, 2014). At present, the application is an open platform and does not differentiate or restrict access between female and male users. As the transactions and exchange of money is done in person and not over the system, the m-Milk cannot control who receives money for the sold milk. This is a social issue that should be taken into account when evaluating the system, but as there is little evidence to date about whether or not women have access to the family phone nor on whether women would continue to handle the money if such a system is in place. It is an issue to be keenly aware of in evaluation, but should not preclude testing the system in the field.

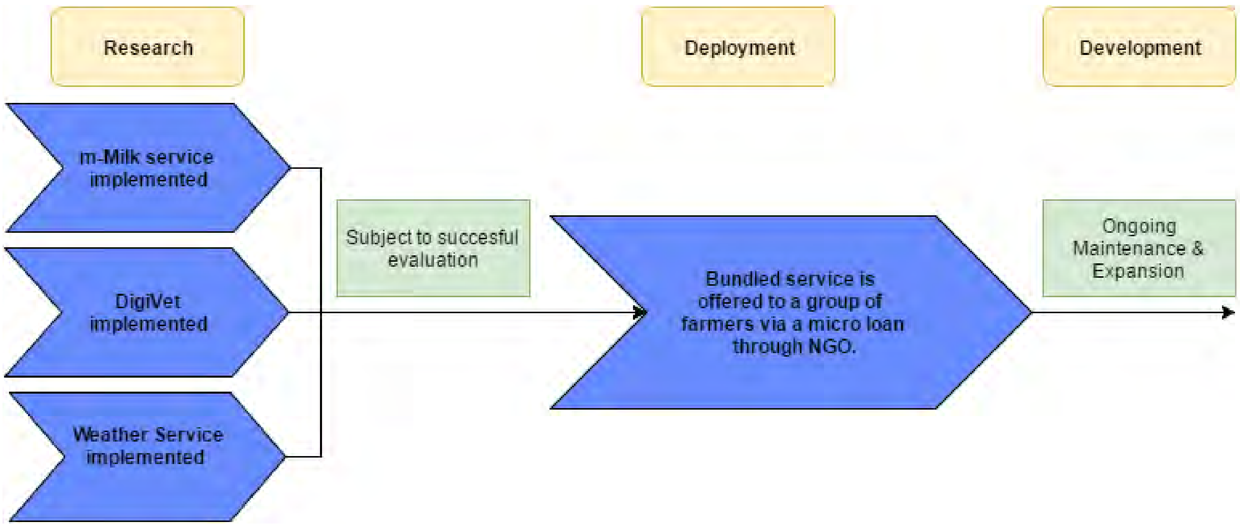

Figure 10: Deployment Model for the m-Milk service

14 Deployment

As (Ho et al., 2009) have argued one of the grand challenges in the field of HCI4D and more widely for ICT4D, is a system that proceeds beyond the prototype phase into a sustainable long term effort with provable development outcomes. The deployment plan of the m-Milk takes a long-term perspective with different actors involved at different stages, shown in figure 10. For the initial research focused phase, experts from universities and other research bodies work with local contacts in an agile iterative process to bring individual services to a stage where they can be tested and evaluated. If the testing and evaluation indicates that a given service has potential, then services that meet those criteria are bundled together and offered as a bundle with the necessary hardware via a micro loan. Microloans and ongoing support and evaluation will be supplied by a larger organization with the research and expertize in this area. Though funding for projects are often short term, it is hoped that the long-term view will help find partner organizations early in the process and setup a pipeline for long term development. Different actors with different expertize will be involved in each of the Research, Deployment, and Development stages of the process in line with the general consensus at the ICT4D symposium about the need for an interdisciplinary approach to development and the experience of long-term projects presented by (Stubbe, 2016).

15 Future Work

The MoSCoW model described under key requirements in section 3.0.11 recognized several additions to the Mali Milk Service. As outlined previous a simple visual interface using a computer has been implemented, which could be expanded further through data extraction. This could be done by implementing a more structured data collection, as RadioMarche(Gyan et al., 2013) does, where the amount available of the given product is stored in a more structured way than an audio file. Having this structured information would make displaying how much milk is available in a given area easy and aid organizing transport to collect the excess milk and bring it to a dairy. For users of the phone based system, implementing a way for users to navigate through the potentially many milk offer messages would be a useful function. At present no data is extracted from the phone calls aside from the voice messages. A simple way to get the information would be to use dtmf, but this would only be useful if farmers have less than 10 liters of milk for sale per day. This might be the case as Victor estimated 3-4 cows per farmer which will each produce around 4 liters of milk, yielding 12-16 liters of milk a portion of of which will be consumed by the farmer and extended family(de

Boer, 2016). If the amount of milk available per farmer is greater than 9 liters then a two phase system could be used where farmers first select if they have between 1-10 liters or 11-20 liters available and so forth as needed. Then we could extract first the tens of liters, then ask the farmer to key in the ones using dtmf, which we can combine and save as 21-30 = 2 tens and 7 ones as clicked by the farmer, saved as 27 liters of milk. The last enhancement to the KasaDaka is also shown in Figure 10. The m-Milk application alone should to be insignificant for a farmer to purchase because the KasaDaka could host more services at the same time. This proposed "package of services", needs to be evaluated as shown in the deployment phase. The limits depend on the workload of the KasaDaka, but a well designed package, with for example weather and digital vet services, could be delivered to the farmers.

16 Conclusion

The Mali Milk Service application is a simple, yet potentially effective way of dealing with some of the identified problems faced by farmers in Tominian Mali. The service help milk producers reach buyers in a more efficient way than going door to door and provides a means of organizing pooling and processing of milk in the rainy season when milk is relatively plentiful. By using the same service and telephone number for the farmer and the buyer, the service is kept simple and easy to use. This makes it easy to maintain, and aides expanding the system to other parts of the Sahel. To ensure that the application is financially sustainable, a deployment plan where several services are bundled onto a KasaDaka to increase the benefit relative to costs has been suggested. This bundle could then be offered by an NGO via a micro loan system, where the farmers can gradually pay off their KasaDaka and added value bundle. To ensure scalability local languages can easily be added, by recording and implementing new audio messages. The option to create a new cooperation creates a network where Tominian farmers can benefit by splitting transport costs or sharing information on farming. For existing cooperatives it offers a way to increase efficiency and reaching more farmers and buyers.

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Appendices

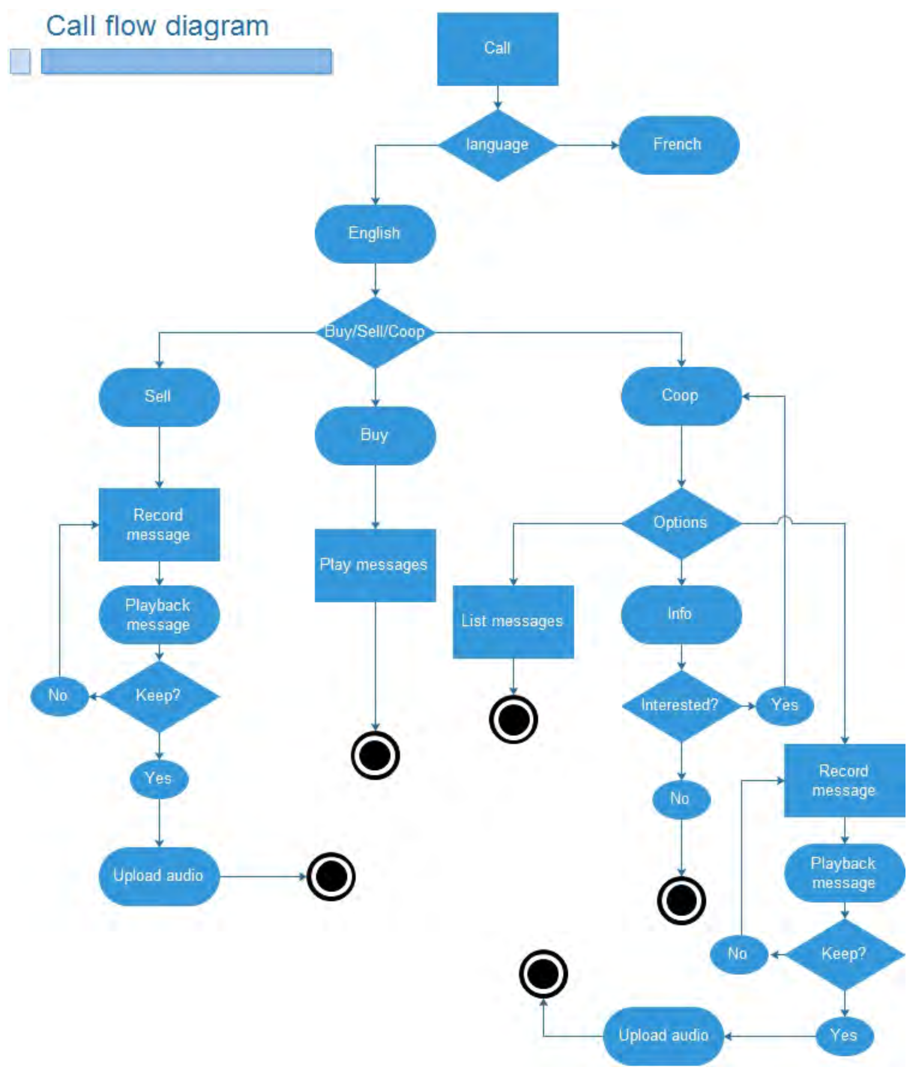

Figure 11: Call flow Diagram V3

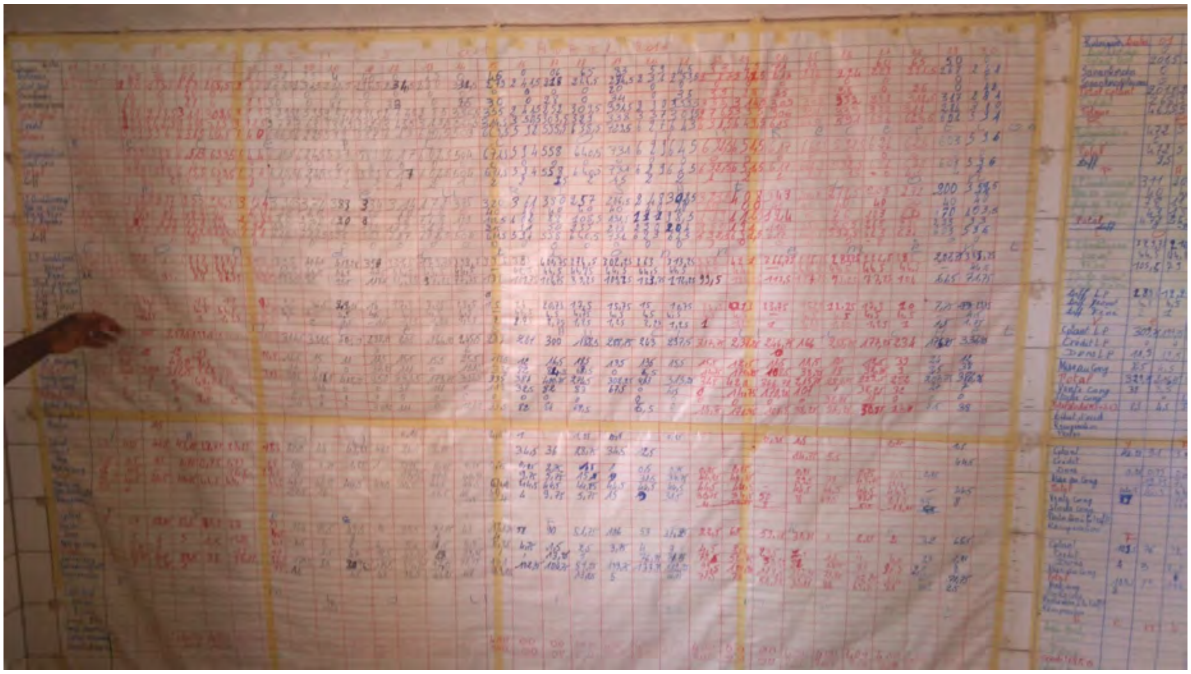

Figure 12: Picture of the offline data model

Main Menu	Welcome to the Mali Milk Service
Buy Route	For Language Press 1
Sell Route	To hear milk offers, press 1. To offer milk for sale, press 2. To hear about co-ops and express interest in joining, press 3.
Co-op Route	If at any point you want to return to the main menu, press 9.
Error Catching	Please listen to the following offers from farmers
	To hear messages again, press 1, else hang up. Thank you for using the Mali Milk service.
	There are no messages at present, please try again another time.
	Please leave a message after the beep, with name, phone number, location, and available milk. When you are done, press any key.
	Here is what you recorded
	To record a new message, please press 1. To keep your message, press 2.
	Thank you for leaving a message. Goodbye
	To hear information about co-operatives, press 1. To hear messages from people interested in starting a co-op, please press 2. To record your own message, please press 3.
	Setting up a cooperative is a way to get organized with other farmers to help each other. With a co-op you can organize transport to bring everyone's milk to the market or to bring sick animals to the vet.
	To listen again press 1. To hear messages left by other farmers interested in starting a co-op, press 2. To record your own message, press 3.
	Please leave a message with your name, phone number, and village so others can contact you. Press any key when you are done.
	Please listen to the following messages from other farmers
	To hear the messages again press 1. To return to the other options, press 2.
	I did not hear anything, please try again.
	I did not recognize that, please try again.
	Message not recorded, please try again.

Figure 13: Scripts for Audio Recording

THE MALI MILK SERVICE

GETTING IT UP AND RUNNING ON THE KASADAKA

Required:

- Kasadaka with power cable and setup according to instruction guide.
- Internet connection or SD card with project code.

Project Installation

Get code and audio files from either online repository or SD card:

- Cd to the /FlaskKasadaka/FlaskKasadaka directory.
- Clone the mali_milk repository from https://github.com/asroben/mali_milk
- Copy and paste the content of the /mali_milk folder into the FlaskKasdaka directory – replacing all files when prompted.
- Activate the virtual environment from a terminal in the FlaskKasadaka directory:
  source FlaskasadakaVenv/bin/activate
- **Pip install flask**
- **Pip install path.py**

Asterisk

Make the following changes as the root user:

- Change one or more of the extensions in the /etc/extensions.conf file to direct calls to: 0.0.0.0:5000/ voice so you can call the service.
- Copy and paste the updated vxml.conf content from: https://github.com/abaart/KasaDaka/blob/master/etc/asterisk/vxml.conf (to fix recording issue)
- Restart Openvxi: **sudo service openvxi restart**
- Restart Asterisk : **sudo service asterisk restart**

Running the Service

- From the FlaskKasadaVenv virtual environment use python __init__py to start Flask serving.
- Call the service to make sure it is running.

Trouble Shooting:

- Some issues, like linphone hanging up immediately on the virtual kasadaka can sometimes be solved with **apt-get update**.

Figure 14: Installation Guide for the Mali Milk Service

A Structured Model-Based Approach To Preview Sustainability in ICT4D

Anna Bon, Jaap Gordijn, and Hans Akkermans

The Network Institute - Vrije Universiteit Amsterdam,
De Boelelaan 1081, 1081 HV Amsterdam, The Netherlands.
(a.bon,j.gordijn,j.m.akkermans)@vu.nl

Abstract. e-Services have great potential, even in resource-poor environments such as in sub-Saharan Africa. However, contextual factors pose significant challenges for development, feasibility, deployment and sustainability of e-services. Based on extensive field research over many years, we describe a structured methodology to analyze sustainability of innovative services. This is illustrated by a case of e-service innovation in a rural context in Mali, with targeted end users in regions characterized by limited internet access, strong diversity in languages spoken, high illiteracy rates and limited purchasing power.

1 Introduction to e-Service Innovation in Rural Africa

Despite the many information and communication opportunities offered by the World Wide Web, over 4 billion people are still unconnected. Many of them live in remote rural regions of the world.

Recent field studies in West Africa have demonstrated that there is a demand for relevant, timely and accurate information for rural communities (Aker, 2008; de Boer, De Leenheer, Bon, et al., 2012; de Boer et al., 2015). Information about market prices, local daily rainfall and local weather predictions, information on animal diseases and health management of e.g. cattle and sheep, are just a few examples of information, considered important by local farmers (Bon, de Boer, Gyan, van Aart, et al., 2013; Gyan et al., 2013). This demand for information may be served by context-sensitive e-services that provide relevant information to local rural populations.

Accordingly, an important issue in rural development is how such e-services can be developed and deployed in *a sustainable way*, given the local conditions that are vastly different from the usual 'normal' urban contexts that dominate scholarly research.

In this paper, we consider service sustainability issues in rural areas of Mali and neighboring Sahel countries (e.g., Burkina Faso, northern Ghana) in West Africa. Electricity is scarce or even non-existing in many rural regions and villages, and internet and computers are hardly available. Low literacy is common (e.g., in Mali adult literacy is below 35%). In Africa, a wide variety of local languages are spoken, and most of them are to date not properly supported by the Web or other computational means. Purchasing power is limited, with an average income of less than 2 US$ a day.

A positive condition is the widespread availability of mobile telephony among rural people, and the wide availability of community radios in rural Africa (De Bruijn, Nyamnjoh, & Brinkman, 2009; Bon et al., 2012).

This paper outlines — based on extensive field research over the period 2009–2016 in rural Mali in which a voice-based microblogging e-service was developed and deployed with local stakeholders — a methodology to upfront analyze business model *sustainability* for e-service innovation in severely resource-constrained contexts.

This is important to investigate, as developers of ICT systems and e-services are often unfamiliar with this (rural African) context, and consequently many well-intended ICT projects fail. Conversely, the local envisaged end users are unfamiliar with ICT and e-services. A farmer in Mali may be interested in a new mobile e-service. However, she will only pay for the service when it creates added value for her. Another actor in business, say, an enterprise such as a radio station, may be interested in participating in future commercial voice-service delivery. However, the profitability and sustainability of an innovative e-service is not obvious beforehand for the radio station.

In sustainability analysis, some key insights are worth pointing out. First, business model analysis is commonly carried out from a single-enterprise viewpoint (Osterwalder & Pigneur, 2013); however, for sustainability it is crucial to take into account the whole socio-economic and socio-technical *network of actors* (Gordijn & Akkermans, 2001, 2003).

Second, as will be shown, analysis yields more than one business model that may be feasible and sustainable; they are associated, however, with different roles and network configurations of involved actors, and they moreover have different implications for the ICT requirements.

Fig. 1. The rural context in West Africa, without electricity or internet infrastructure.

2 Sustainability and the *e*³*value* methodology

As is the case with any innovation, long-term (financial) sustainability of is key to success. To develop an economically sustainable value web, each participating actor or enterprise must be capable of making a (long-term) profit or derive other forms of use or exchange value by being part of the value web.

In general, e-services based on networked technologies are usually provided in *networked constellations* (see e.g (Normann & Ramírez, 1994)), or, as we call them, *value webs*, in which each enterprise brings in a specific core competence. All these competences of the participating enterprises in the value web jointly satisfy a customer need, which could not have been satisfied by a single enterprise.

Likewise, innovative mobile/web services in Africa consist of networked constellations. These value webs may look different from a high-tech e-commerce setting, as they involve actors such as radio stations, low-tech intermediaries (e.g. middle-men, local organizations etc.) and paper-based transactions. The speed of transactions may be slower than in Internet-based e-commerce, especially by the absence of on-line payment services. However, we argue that the concept of value web is valid in low-tech, constrained rural contexts, as will be shown by the case of a voice-based radio platform, deployed in Mali.

To accurately analyze different (business) scenarios for a given e-service, and evaluate/predict their feasibility and sustainability, we propose a model-based assessment of network profitability based on the e^3*value* methodology. e^3*value* [1] is a conceptual modelling tool for qualitative and quantitative assessment of the feasibility and sustainability of a business idea (Gordijn & Akkermans, 2003, 2001). Figure 2 gives an illustrative example of a simple e^3*value* model, showing a customer buying an ice cream at a snackbar, and paying for it. The snackbar in turn obtains the ice cream from the ice cream factory and also pays for it. The example explains the various basic ontological concepts of the e^3*value* method (The following text is an excerpt taken from (Gordijn & Akkermans, 2003, 2001)).

The model in Figure 2 shows various *actors* in a *value network*. Each actor represents an individual entity, which is responsible for profit-and-loss. This can for example be a customer, an ice cream factory, a shop, any business. Actors can be represented as single or multiple entities: in the latter case they represent a whole market segment. A market segment is in fact a set of actors that share the same economic utility function. Market segments are represented graphically in the e^3*value* ontology as a 'stack of actors'. (For the sake of simplicity, the market segment is not represented in the example of Figure 2).

Actors in a value network exchange value objects with each other. These value objects (e.g. an ice cream, money) represent an economic value for the actors in the model. Actors exchange (provide or require) value objects via value ports. Value ports are grouped into value interfaces. These value interfaces model the economic reciprocity, which exists in every business transaction. Evidently, an

[1] See http://e3value.few.vu.nl

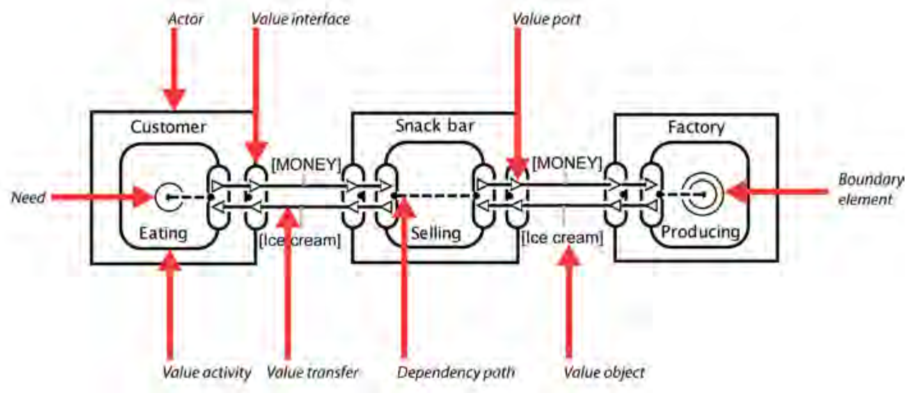

Fig. 2. An educational e^3*value* model.

actor provides a value object, only, if he or she gets something in return, of equal or higher value. In Figure 2 a customer and a snack bar exchange an ice cream for money. This occurs through a value transfer. This models the actual transfer of the value object (the ownership of the ice cream is transferred from the snack bar to the customer). Given the reciprocity principle, when an ice cream is transferred, money is transferred in the opposite direction[2].

A customer need initiates the business process: in this case, the customer wants to have an ice cream. To satisfy this need, an exchange of value objects (ice cream against money) via an interface. This is modelled by connecting the value interfaces by dependency paths. It becomes clear that the snack bar must obtain the value object (ice cream) from the ice cream factory. A boundary element at the ice cream factory, indicates where this value transfer actually ends (which demarcates the scope of the model).

The e^3*value* model makes it possible to calculate a net cash flow for each actor in the value network, and can therefore serve as an indicator for feasibility of the value network as a whole.

3 Developing a Micro-blogging e-Service in Rural Mali

In the framework of the W4RA[3] research program, an interdisciplinary, international team (consisting of requirement engineers, information analysts, web developers, speech technologists, sustainable land management specialists and business experts) developed innovative e-services in Mali, in close collaboration

[2] The relative timing of the various transfers is not represented in the model, only the nature of the transaction as a whole

[3] The Web alliance for Regreening in Africa, http://w4ra.org

with local radio journalists, local African non-governmental organizations and smallholder farmers.

The co-creation took place during extensive workshops and focus group discussions in Bamako, Segou, Konobougou, Tominian and San, in Mali. The workshops aimed at understanding the context, reducing cultural distance between all stakeholders, elicitation of the ICT and business requirements, showing prototypes, and evaluating technical architecture and business models. Various e-services were deployed during an extensive field experiment in West Africa, between 2009 and 2016[4].

One of the developed e-services was a voice-based micro-blogging service, that allows people from rural villages in Mali, without Internet, to send a voice message (by mobile phone) to the local radio, for broadcasting. The use case data for this voice-based micro-blogging service were collected in 2011 and 2012, in collaboration with local Malian non-governmental organization Sahel Eco and three Malian radio stations, who requested a (mobile) service where customers can phone in and leave a spoken announcement for broadcast. The radio journalist can access and manage the incoming (spoken) messages via a web or mobile/voice interface. The radio station charges a fee for broadcasting the message. The name given to this service was Foroba Blon[5].

In this study three examples of a voice and radio-based e-service are shown, developed and deployed in rural Africa, in close collaboration with the local end-users. During the workshops, several actors were identified, who would make up the value web for e-service delivery and consumption. The following information was collected during various focus group discussions with radio journalists, local NGO staff members and farmers.

Fig. 3. Radio Sikidolo, in the village Konobougou, Mali.

[4] For a full description of the e-services and the use case and requirements analysis for these services, see (Bon et al., 2013; Gyan, 2016)

[5] The Foroba Blon e-service was part of the project with the same name, funded by the International Press Institute, see http://w4ra.org/foroba-blon-community-radio-in-africa-and-the-web/

3.1 Rural radios, the potential service providers

Rural radios are important local information providers/hubs in rural Africa, in the absence of other mass media. The Malian community radios in our study reach about 80,000 listeners, within a radius of coverage of 100 to 200 km. They create programs and broadcast local and regional news, music, round table programs and paid announcements. Some of these radios in rural Mali have computers and a connection to the Internet, some only have computers without Internet connection, some have no computer facilities at all, depending on their business size and location. All radio stations are situated within the coverage area of (2G) mobile telephony.

Fig. 4. Radio Moutian in Tominian, Mali.

Rural Radios in Mali are publicly funded (ORTM[6]), community-based or privately funded. Some radios receive donor aid. All radios sell broadcasting air-time. Different fees are charged for commercials than for private announcements.

Three radio stations were involved in this research project:(i) Radio ORTM Segou, a state owned radio, that has computers and a fixed Internet connection (DSL). Radio ORTM Segou broadcasts programs in French and Bambara, the most widely spoken language in Mali; (ii) Radio Moutian, in Tominian, an independent radio, selling airtime for announcements and receiving some private gifts from third parties. Radio Moutian has a computer but no Internet connectivity. Programs are mainly broadcast in Bomu, a local language in the Tominian

[6] https://en.wikipedia.org/wiki/Office de Radio diffusion et Télévision du Mali.

region; (iii) Radio Seno in Bankass. This radio is independent from the Malian state and has only analogue equipment. There are no computers, there is no Internet connection here, but the radio has many listeners in the area around Bankass. The language spoken here is Dogon. The activities of the three above mentioned radio stations are related to different types of customers and business contacts.

3.2 Village reporters as service providers

Journalists or trusted village reporters work for the radio and leave local news or interviews on a regular base. In the current situation, all incoming phone calls are attended by a radio staff member and annotated in tabular form on paper.Radio reporters in the villages provide mobile phone access to villagers (non-commercial radio-listeners), who want to send an announcement to the radio, but do not own a mobile phone. These radio reporters also arrange the payment for the broadcast between the villager and the radio.

3.3 The potential customers

The proposed voice-based micro-blogging e-service has three types of customers (actors as a market segment).

1. Non-commercial radio listeners living in the surrounding rural communities buy a few minutes of airtime and pay a broadcast fee per minute airtime. Their average income is usually between 1 and 2 US$ a day. The information is usually brought to the radio on paper, or communicated via phone and subsequently written down on paper by the radio staff. These announcements can be e.g. about weddings, funerals or other messages to the public.
2. Non-governmental organisations (NGOs) buy airtime to broadcast public announcements about informative and educational topics, such as agriculture and public health information. They pay the radio a fixed monthly subscription fee for recurring broadcasts.
3. Commercial services broadcast advertisements on the radio. These were not taken into consideration in the model, but are a potential, future source of income for the radios. The fees charged for commercials are 150 percent of the fee for private announcements[7].

4 Evaluation of business models

The first release of the voice-based micro-blogging system, Foroba Blon, based on local business ideas and requirements expressed by the radio journalists, was tested and taken into in production by Radio Sikidolo, in Konobougou, and radio Moutian in Tominian, in Mali. The technical architecture of the Foroba

[7] Source: personal information by Adama Tissougué, Radio Sikidolo, May 2016

Blon platform has been published [8]. The technical architecture of the Foroba Blon platform has already been published (Gyan et al., 2013; Bon et al., 2012).

We received extensive feedback from the radio journalists about the assets and the problems they experienced while using the Foroba Blon system. This feedback was used to construct value models, based on real and estimated costs, and used to predict feasibility[9].

Fig. 5. Members of the Foroba Blon team at Radio Moutian, Tominian, Mali, February 2012.

Three business models for potential e-services were designed and analyzed for Foroba Blon. The first model uses a village reporter, who owns a mobile phone, to send messages from people who do not own a mobile phone to the Foroba Blon system. For this, the village reporter obtains a small fee. The second business model supposes professional users, such as a NGO, who wants to send messages. These professional users pay a small fee for sending their messages. The third business model is about a news provider who wants to obtain news items from the local region. The news provider can be a newspaper or a television station who wants to have content (the news items) to broadcast. For receiving local news, the news provider pays a fee.

The three business models are evaluated for feasibility and sustainability. Each of the models is associated, however, with different roles and network configurations of involved actors. Each model brings therefore, different implications for ICT requirements.

[8] A documentary about Foroba Blon can be viewed at http://w4ra.org/citizen-journalism-in-rural-areas-in-mali/

[9] Source: personal information by Adama Tissougue, Radio Sikidolo, Mali, May 2016

4.1 The village reporter-based business model

Figure 6 presents the e^3*value* model for the village reporter service. Senders, being individuals without access to a mobile phone, can contact a village reporter. A village reporter is a person who normally collects news items for a particular local area and reports these items to a local radio station. For this purpose, the village reporter owns a mobile phone, and is also trusted by the local radio station.

A sender is for instance a herder in Mali (e.g. Konobogou). He wants to broadcast a message on the radio, e.g. because he is missing one of his cattle. By reporting this lost animal on the local radio, the message will reach about 80,000 people, the listener's base of this small radio Sikidolo, in Konobougou. The chance of finding the cow and reporting this is substantial. The sender is willing to pay 1000 CFA for one minute of broadcasting a message on the radio, plus the cost of the phone call (100 CFA[10] per minute) to have access to the FB platform via mobile phone. The alternative would be to travel to the radio station to leave the message personally. The travel to reach the radio station would cost him (the sender, in casu herder) on average 4000 CFA.

This idea for this business model is that customers (senders) who do not have a phone, can use the mobile phone of the village reporter to send their announcement they want to broadcast to the radio station. The village reporter gets paid a percentage of the broadcast per delivered message. Note that the 'delivered message' transfer points *towards* the sender, as delivery of the message is of value to the sender. In case a business process diagram (so not an e^3*value* value model) would be presented, the message itself would flow into the direction of the village reporter and local radio station.

Additionally, the village reporter pays a fee to the local radio station per delivered message, and (denoted by #1) pays a fee to the mobile operator (Telco) for delivering a telephone call. Because senders have to pay more to the village reporter than the reporter has to pay to local radio station and telco per message, the village reporter has a small profit per delivered message.

The local radio station broadcasts each message to its receivers. The explosion element (denoted by #2) indicates that one message received is broadcast to many receivers. Also, the local radio station needs to have Internet access in order to obtain voice messages from the voice service platform (see below). Therefore, the local radio station pays a fee to an access provider for having Internet access.

Foroba Blon acts as a service platform provider for handling voice messages. To this end, the local radio station pays a monthly fee to Foroba Blon. Foroba Blon needs to host its platform and needs IP transit (Internet connectivity and connection to the phone network). Such hosting is outsourced to the hosting provider for which Foroba Blon pays a fee.

Implications for ICT requirements

The village reporter-based business model was designed and built following an existing practice and workflow at Radio Sikidolo, which came up with the initial

[10] CFA is the currency in Mali, 655 CFA equals 1 EUR

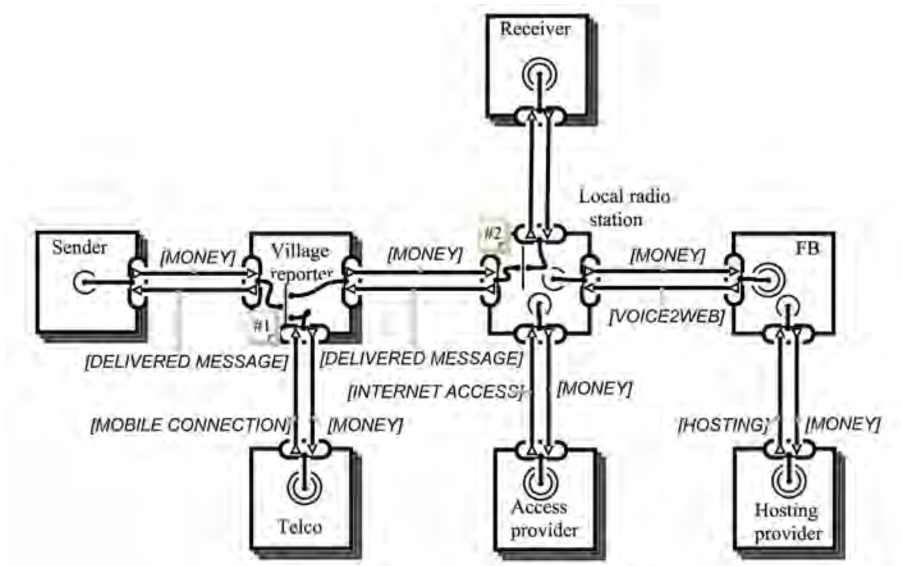

Fig. 6. The village reporter as a middle man between news senders and the radio station.

idea. The first cycle deployment was done and radio journalist Adama Tessougué tested the system with a number of village reporters. He was pleased with the system and came up with some technical adjustments and new requirements, which affect the technical design and the business model:

- A notification message must be sent as an sms to the radio, once a new message has been issued. Since Radio Sikidolo had no Internet at the time of first deployment (2012) so he had to phone in to the Foroba Blon system. When testing the system, the radio spent several phone-calls to access the Foroba Blon system, while no messages had been issued. Since the cost of a phone call in Mali are relatively expensive, this was an important cost-driven IT requirement.
- A mobile payment system, so that the broadcast service can be paid to the radio, was one of the requirements, to avoid cumbersome cash transactions between the radio and the village reporter. Moreover, paying in advance discourages people to phone in to the Foroba Blon service and leave fake messages. During the first cycle, mobile payment systems were not available for mobile operators in Mali (the main ones here are Orange and Malitel). In 2013 local mobile operator Orange launched Orange Money as mobile payment system in Mali [11]. Operator Malitel followed soon with an similar service. This facility is, however, not yet implrmented in Foroba Blon. An application programming interface provided by the local mobile operators

[11] http://www.orangemali.com/omoney/

(Orange, Malitel) allows further development of modules for mobile payment (based on mobile airtime).

4.2 The radio-based advertisement business model

The second value model for Foroba Blon has a different type of customer, e.g. a commercial business that want to advertise a product or service, an NGO, or governmental department that wants to send information to a broad audience, e.g. on health, agriculture, education etc). In fig. 7, in our model the customer is called the sender, as the customer wants to broadcast a message (e.g. an ad) to a large audience.

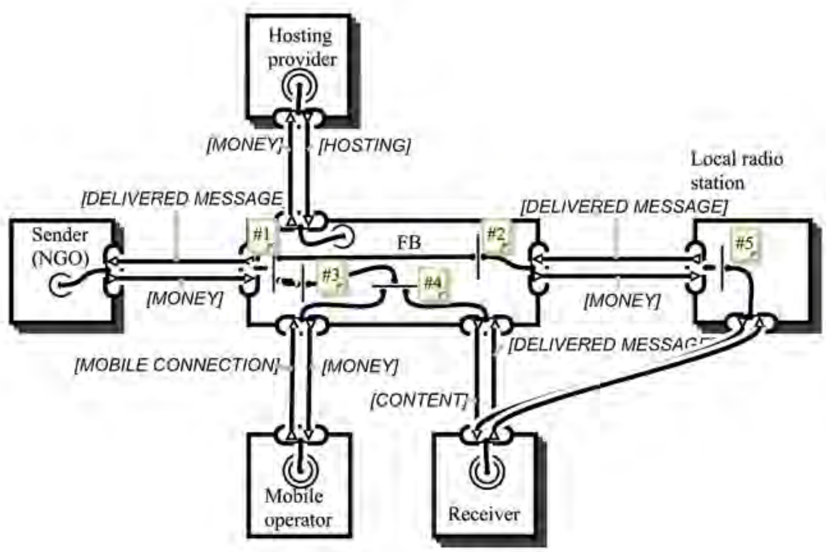

Fig. 7. The sender pays directly to Foroba Blon.

The sender obtains from Foroba Blon a delivered message and pays a fee in return. Note that in this model, Foroba Blon is the commercial entity the sender deals with it,in contrast to the village reporter-based business model where the radio station is the party the sender deals with. Then the AND fork annotated with #1 indicates that two things happen: (1) the message is broadcast via radio stations, and (2) the message is sent via mobile phones to receivers.

In case the message is sent via radio stations, the upper dependency path is followed (inside Foroba Blon). The explosion element marked #2 indicates that one message can be broadcast via multiple radio stations, thus reaching a larger audience. The local radio station delivers the message to its listeners (the receivers) and gets paid for that by Foroba Blon.

The message is also sent via mobile phone connections to subscribers. This is represented by the lower dependency path inside Foroba Blon. The explosion element marked as #3 shows that one message is sent to multiple receivers. The AND fork annotated with #4 indicates that for the delivery of a message to a receiver, there are value transfers necessary for the mobile connection (with a mobile operator) and for the message delivered to receiver.

The receiver provides the service of a *delivered* message to Foroba Blon (or the radio station). Similarly, Foroba Blon offers a delivered message to the sender. As message delivery is of value to the sender, the related transfer points towards the sender. It supposed that content of the message is of value somehow to the receiver. Consequently, there is a value transfer from Foroba Blon and the local radio station to the receiver representing the economic value of the content of a message.

Implications for technical/user (ICT) requirements Based on user feedback and evaluation of the models, the technical architecture is refined and re-adjusted. New requirements that came up after the business model was designed were as follows:

- Since the sender in this case has an Internet connection, a new requirement is a web interface where the sender can enter the message to be broadcast;
- A new requirement by the NGO was to add the possibility to stream the message to a number of phone recipients, in stead of sending it to radio for regional broadcast; with this addition, the message can be optionally sent to a limited number of recipients, if the sender wants to reach a limited number of known contacts (e.g. to invite 50 recipients for a meeting or event).

4.3 The citizen journalism-based business model

This business model supports citizen journalism in e.g. rural Mali. This model shows an information pull, in which local reports by village reporters and local citizen journalists are requested by the customer, which is e.g. a large media company (the news provider).

The news provider (e.g. Al Jazeera, CNN, ORTM, BBC, Wereld Omroep) needs news items (content) for their programs. Part of this content is obtained from regional reporters in the field. This is especially interesting regarding unstable political situation in northern Mali, where incidents may take place, reported by eye-witnesses and village reporters, or during presidential elections, e.g. in Ghana or Kenya, or during e.g. ebola-outbreaks in the country. News providers pay a fee per news item to Foroba Blon. The role of Foroba Blon is to obtain voice-based news messages from local radio stations. Local radio stations are paid a fee per delivered news item. In order to facilitate delivery of news items by local reporters via mobile phones, Foroba Blon has a contract with a mobile operator. The value model in Figure 8 shows that Foroba Blon pays per news item a mobile operator fee for a telephone connection. Note that Foroba Blon pays for the phone connection, not the reporter. In reality, this is implemented

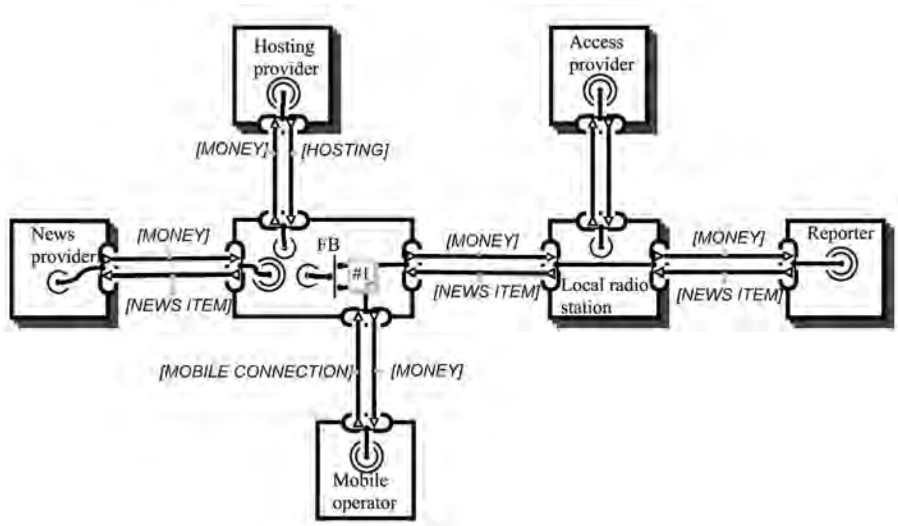

Fig. 8. The news provider pays for obtaining regional news items.

as a toll-free number that reporters can use for free, while Foroba Blon pays for this toll-free number.

Local radio stations in turn obtain news items from freelance reporters. In turn, these reporters are paid a fee per news item. The radio station also organizes and enriches each news item with some meta-data, such that it can be easily be accessed online by the customer.

Implications for ICT requirements The technical design of this business model is similar to Foroba Blon model 1, only the business case is different, because different values are transferred. The village reporter now sells his voice report to the news provider, in stead of buying broadcast airtime from the radio. This asks for the following additional technical requirements:

- A payment module should be built into the web interface of the customer, in which the radio and the individual reporters are remunerated for each relevant report they enter into the system;
- The radio station, who operates as the intermediary between the village reporter and the customer, has an Internet connection, to do the management of the content, and the payment to the village reporter;
- A toll-free number is provided by the telecom operator for the village reporter, who no longer pays for entering a message. He receives a payment for each spoken news item entered into Foroba Blon and accepted by the customer.

4.4 Discussion of the development process of the models

The first model we designed and built was based on an idea from the local radios. The service replaces an existing (legacy) work flow, which was an existing, cost-effective, legacy broadcasting service from the radio to the rural community. The customer and the radio station experience improved efficiency once the Foroba Blon service was operational. Radio journalist Adama Tessougué tested the Foroba Blon system with a number of village reporters in Konobougou and surrounding villages. The second and third value models are examples of new services that were adaptations of the initial service. Value models 2 and 3, described above, were non-existing previous to the Foroba Blon deployment. These models represent a local innovation — or rather a local reinvention — as a consequence of the introduction of an innovative technology in this local rural (constrained) environment.

In models 2 and 3 the village reporter (or farmer, or rural community member) is no longer the customer or sender in the value model, but a service provider or a targeted market segment. The farmers provide the listener's-base, for the customer (NGO, or advertiser, etc.) who wants to send information or advertisements. In models 2 and 3, the radio no longer pays for the Foroba Blon service, but receives the payment from the Foroba Blon provider to provide a service. The telecom provides the phone calls to and from the Foroba Blon platform and receives payment from Foroba Blon provider, so that reporters can use toll free numbers e.g. to enter information in model 3, or to receive or access information in Foroba Blon model 2. A service provider that wants to deploy the Foroba Blon mobile/web platform in Mali, will try to maximize the profitability of its services and deploy these three services simultaneously. However, numerous other types of voice-based radio services can be designed and deployed, once the Foroba Blon voice-based platform is up and running, and the technical obstacles have been solved.

5 Concluding Remarks

An important goal of the presented approach is to get to e-services through local value webs that are economically sustainable, also under highly resource-constrained conditions such as in sub-Saharan Africa.

Consequently, a sign of success (and an external validation) is where other parties (such as commercial entities) consider the e-service as useful and viable. The key user of the service, Radio Sikidolo in Konobougou, Mali, has used the Foroba Blon system with 50 village reporters, to make radio programs and broadcast reports from neighboring villages. Moreover, the Foroba Blon e-service was used by Al Jazeera for monitoring the presidential elections in Ghana (2012) and Kenya (2013). The Foroba Blon service has won the News Innovation Contest 2011 from the International Press Institute [12].

[12] http://www.ipinewscontest.org/news/congratulations.html

The presented approach shows that it is possible to obtain important assess future sustainability in a structured and systematic way at an early stage. A key characteristic to be able to do so is the analysis of the *actor network as a whole*, and investigate different possible configurations and scenarios.

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Low profile data sharing with the Entity Registry System (ERS)

Mihai Gramada[1], Christophe Guéret[2]

[1] VU University Amsterdam, De Boelelaan 1105, 1081 HV Amsterdam, Nederland
gramada.mihai@gmail.com
[2] British Broadcasting Corporation
christophe.gueret@bbc.co.uk

Abstract. The entity registry system (ERS) is a decentralized entity registry that can be used to replace the Web as a platform for publishing linked data when the latter is not available. In developing countries, where off-line is the default mode of operation, centralized linked data solutions fail to address the needs of the communities. This project aims to investigate ERS behavior in complex realistic scenarios.

Keywords: Linked data, Decentralized System, ICT4D, RDF, ICT4S

1 Introduction

Applications tend to consume and produce more and more data with each passing year. In order to cope with this increasing volume, some of the work of interpreting and connecting the various pieces can be shifted to the machines that process it. Linked data aims to accomplish this by providing some structure to the data.

Most linked data applications utilize a central repository that is always online and can be interacted with by the users. However, always online connectivity is not guaranteed in developing countries, especially outside of the major cities. Current estimates indicate that approximately 4.1 billion people live with limited to no internet access [3].

In order to address the issue of deploying applications that utilize linked data in limited connectivity circumstances, under a grant from Verisign[3], the Entity Registry System (ERS) has been developed. Its goal is to replace the Web as a platform for publishing Linked Data when the latter is not available. It proposes a completely decentralized model, where off-line is the default mode of operation, with occasional connectivity bursts.

An entity registry provides a way to associate data with an uniquely identifiable entity. ERS is a decentralized, read-write entity registry that allows collaborative editing of entities, which have their data represented in the Resource Description Framework (RDF [4] [10] format. By using RDF tuples as the underlying data representation, ERS can inter-operate with existing linked data

[3] http://www.internetlivestats.com/internet-users-by-country/2015/
[4] https://www.w3.org/TR/2004/REC-rdf-concepts-20040210/

sets, providing a robust system that can be used both online and offline, can be deployed on very low-end hardware as well as high-performance servers and has a high degree of tolerance for sudden network and topology changes.

The goal of this work is to investigate ERS behavior in complex realistic scenarios. To this end, we needed to make it easy to deploy, configure and orchestrate, in order to create repeatable test scenarios. We also verify that the system functions without ideal network connectivity and low hardware capabilities. This paper is a short version of the Master thesis published at the VU University [6].

The remainder of the paper first introduces ERS in Section 2 and then describes usage scenarios in 3

2 The Entity Registry System

An ERS deployment is articulated around the usage of three different type of components [5], all together sharing a single data space.

2.1 Components

There are three main components:

- Contributor: The contributors can read and write the content of the registry. In the general use case, they would be represented by the laptops of the children, with the content of the registry being the linked data that various activities produce. Examples of such activities may be contributions on a shared document, notes on various book chapters, etc. This data is stored locally and can be distributed (if made public) whenever connectivity is present.
- Bridges: Bridges provide a means to connect different isolated parts of the system in order to distribute public data from the contributors. They do not need to reside in the same physical location as any of the contributors and can share public data provided to them with bridges in any other locations. Their functionality is similar to that of a cache, in the sense that if a part of the network goes down, public data can still be read from the bridges to which it was previously connected. Of course, due to storage constraints, data is stored only temporarily on the bridge.
- Aggregator: ERS deployments can benefit from the presence of an aggregator, which would ideally be deployed on a high-performance server or cluster. This optional component can provide a top-level entry point to the whole system, enabling fast read-only retrieval of the public data. Contributors and bridges can push data to the aggregator for it to be available publicly.

[5] More details about the system can be seen on the Github page [3]. For more in-depth analysis, the interested reader is referred to the paper describing the system [4].

The example in Figure1 shows a deployment with contributors and bridges in multiple geographical regions (R1 through R4). For more details on how the details of the interactions between the various types of instances, refer to Gueret et al[4].

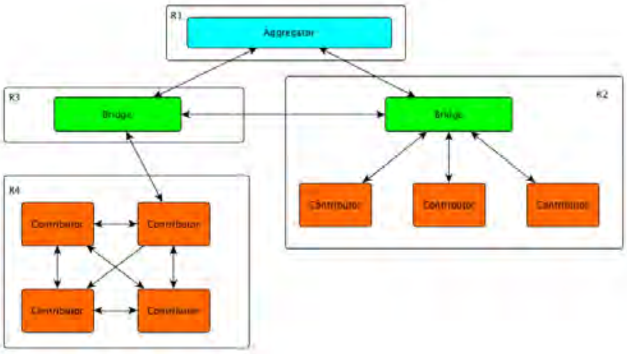

Fig. 1. Sample deployment with 4 geographically separate regions(R1-R4). All nodes can continue functioning while connectivity is disrupted, and updates can propagate when connectivity is restored between the regions.[3]

2.2 Data stores and synchronization

Each ERS contributor has access to three data stores (represented internally by three different CouchDB databases) : public, private and cache:

- The private stores represents the collection of documents that the user does not want to be visible by any other nodes in the system. Examples of data that is stored here is personal private information for participants to a conference or sensitive business information in the case of a vendor.
- The public store holds statements that can be queried by others and that get replicated by bridges. Examples include a public list of skills and work experience that a conference participant wants to share with others or a list of products and their prices for a vendor.
- The cache contains information that is not local to a node, but has been queried by him. In the case of a vendor, he can have in his cache documents related to prices of other vendors that he does business with, which get updated every time there is network connectivity between them.

The synchronization model proposed by ERS consists of the following parts: contributor-contributor, contributor-bridge, bridge-bridge and bridge-aggregator. In [3] an overview of the synchronization schema used is given. A graphical description can be seen in Figure2.

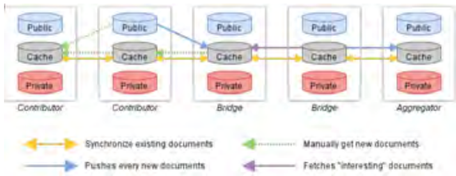

Fig. 2. Synchronization protocol. Updates for documents already in the caches propagate to all nodes who have those documents in their own caches. New document behavior varies by synchronization type. [3]

It is also interesting here to note that ERS allows for conflicting statements. To take one of the two scenarios introduced here as a example, if a, perhaps competing, vendor wants to modify the price list of a different node, he will instead create local documents with the modifications. These do not get merged automatically with the original ones because the CouchDB documents will have different ids. Thus, if node A has only the document of node B in cache, the automatic replication will not get the changes that anyone other than node B makes.

3 Usage scenarios

This section describes two realistic scenarios in which ERS could be deployed. Those scenarios have been simulated to test the suitability of ERS in those contexts [6]. We have chosen the following two scenarios: a social network platform for conferences and a deployment scenario for disconnected remote villages that still need to share data (in this case, price lists of different stores).

3.1 Conference

The purpose of this experiment is to investigate how ERS would perform as a substitute for a social network (such as LinkedIn) in the context of a conference. In this scenario, there are various conference attendees with public profiles, who list their skills and workplace. Attendees can endorse each other for their skills. This scenario contains a static bridge node and various contributor contributor nodes that randomly connect and disconnect, with varying network quality.

Initially, each attendee has on his laptop his public profile. Once he connects to the local network of a particular conference room, he can initiate a search for other participants. He can endorse any other participant for his skills, and these endorsements will propagate to the bridge and thus are visible to all the other attendees.

We observed that the system scales to a larger number of users. With a bridge on a Raspberry Pi 2 model B, it was able to correctly propagate statements between contributors with as much as 40 concurrent contributors.

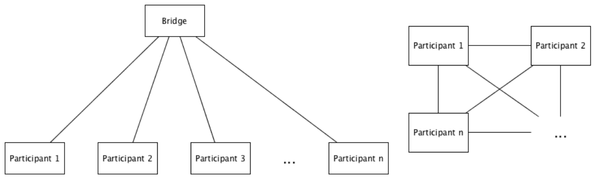

Fig. 3. Connectivity in case bridge is present (left side) and when it is not (right side). If there is no bridge present on the network, each ERS node connects to all the others on the same network, resulting in a quadratic number of connections. The bridge reduces the number of required connections from quadratic to linear.

3.2 ERS Bridge on a truck

This experiment aims to simulate an ERS deployment in a remote location that has no access to the internet, thus removing the assumption that any part of the system (node or bridge) is static and always connected. In Figure4 6 remote villages that each contain a store, and a truck that periodically passes through all of them can be seen. The experiment assumes that in each village there is a vendor that would like to sell or buy products from neighboring villages, and their only means of daily communication and updates is the truck driver that passes through.

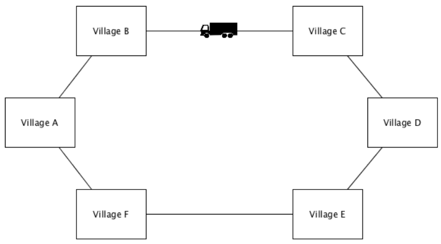

Fig. 4. Mobile bridge experiment. In this experiment, each village has an ERS node, and the truck has an ERS bridge. The truck passes through the villages in clockwise order, propagating updates among them.

In this scenario, we would deploy in each village a contributor node of ERS and on the truck, a bridge node. Each vendor controls the list of items that he is selling and the prices associated with those items in an ERS public document. These documents get uploaded to the bridge the first time it comes in contact with them. Vendors can search for the nodes they are interested in and choose whether they want to cache those entities.

If vendors make modifications to their prices or list of items, these modifications get picked up when the truck passes through his village. Also, when the truck arrives, if he has other vendors in his cache, he will automatically get updated versions of their offerings if the truck stays for at least 5 seconds (this can be as low as 1 second if network connectivity is very good).

Having fixed the number of seconds that the bridge is connected to peers to 5 seconds, investigations have been made into the behavior of ERS in less than ideal conditions. Firstly, the Latency Monkey injects artificial latency into each packet that leaves the system. The system can perfectly handle 100ms of delay(each way) and within the allocated time the bridge and the node will completely synchronize. If latency goes over 125ms each way, the replication procedure will not be able to finish in time for all the nodes.

The next characteristics of poor network connectivity that were investigated are packet loss and packet corruption. In this case the system can tolerate up to 15 percent of the packets being lost or corrupted on each end (the contributor and the bridge). A value that is higher than that will cause rapid degradation in the percentage of statements that are synchronized (in the given 5 second window). Duplicating packets does not seem to have an important effect on the performance of ERS, as no difference has been observed with as much as 60 percent duplication.

In this experiment, the topology was constantly shifting, in the sense that the bridge only had connectivity to contributors for brief amounts of time. We have observed that even with poor connectivity, the system was robust, and propagated the updates.

4 Conclusion

The goal of this paper was to investigate whether it was possible to setup ERS for automated testing, in order to decide if was ready for usage. Through the various functionality tests the correct functionality of various components can be assured. The tests on virtual machines verify that communication between nodes works as expected. The conference simulation indicates that it can scale to a larger number of uses and the truck simulation shows the resilience with respect to poor network connectivity.

Future works should expand the scope of the scalability testing by investigating, for example, how many contributors can be connected to a bridge without losing functionality, or how peers from different geographical locations connected through the internet influence the behavior of the system. An implementation of the aggregator should be finalized and integrated with the other components.

It is usually the case that tests in controlled environments differ from real-world scenarios. Investigating the behavior of the system in an actual deployment should be carried out.

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Demo: Description of Kasadaka

Victor de Boer

VU University Amsterdam

In developing (rural) communities, the adoption of mobile phones is widespread. This allows information to be offered to these communities through voice-based services. This research explores the possibilities of creating a flexible framework (Kasadaka) for hosting voice services in rural communities. The context of the developing world poses special requirements, which have been taken into account in this research. The framework creates a voice service that incorporates dynamic data from a data store. The framework allows for a low-effort adaptation to new and changing use cases. The service is hosted on cheap, low-powered hardware and is connected to the local GSM network through a dongle. We validated the working and flexibility of the framework by adapting it to a new use case. Setting up this new voice server was possible in less than one hour, proving that it is suitable for rapid prototyping. This framework enables further research into the effects and possibilities of hosting voice based information services in the developing world.

The software on Kasadaka is as much as possible Free and Open Source software to allow for community-development and to make it as affordable as possible. The Kasadaka project builds on information acquired from workshops in Burkina Faso, Mali, Ghana and Niger, focusing on the development of ICT services that support regreening activities in rural, often remote areas in the Sahel.

More information can be found at http:/kasadaka.com. The software and details on how to get started with Kasadaka can be found on the project's GitHub page: https://github.com/abaart/KasaDaka

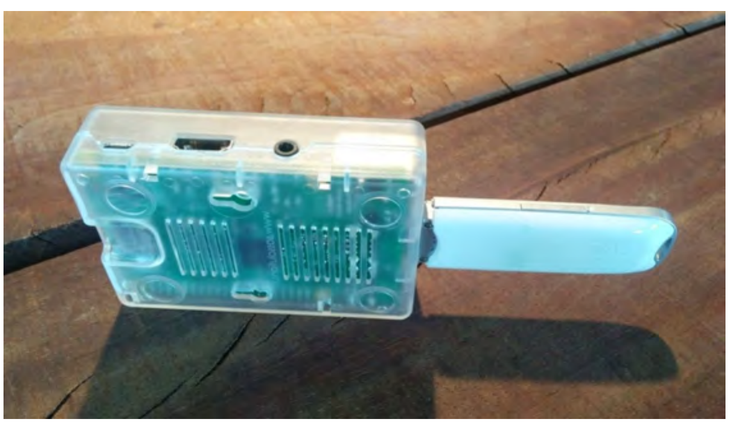

Fig 1: The Kasadaka hardware : a Raspberry Pi computer with a GSM dongle

Demo: the Kasadaka platform

André Baart
VU University Amsterdam

KasaDaka platform

The KasaDaka is a platform providing voice based information services to rural communities in sub-Saharan parts of Africa. This is done while taking into account the various challenges posed by this context, such as poor connectivity, unreliable power infrastructure, as well as literacy issues. In the past year, the platform has become better suitable for rapid prototyping and easy adaptation to new use cases. Currently, the system runs on a Raspberry Pi and GSM dongle. The user calls the KasaDaka over the existing GSM network.

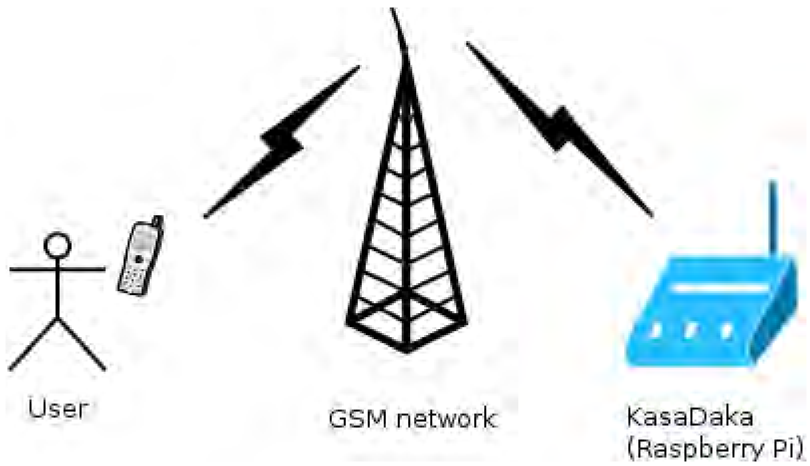

Illustration 1: Model of the KasaDaka system

When a call is made, a number of systems are working together to dynamically generate a voice based conversation. The system goes through the following steps:
Text in *italics only takes place when setting up the call.*

1. *Asterisk receives the call from the GSM dongle, answers the call, and connects it to VXI.* Asterisk receives the user's input and forwards it to VXI.
2. *VXI requests the configured VoiceXML document from Apache.* VXI requests the configured VoiceXML document from Apache. Together with the request, it sends the user input.
3. Apache runs the Python program (based on Flask), in which data from the triple store has to be read or written. Python sends the SPARQL query to ClioPatria.
4. ClioPatria runs the query on the data present, and sends the result of the query back to the Python program.
5. Python renders the VoiceXML template. The dynamic data is now inserted in the VoiceXML document, and it is sent back to VXI.
6. VXI starts interpreting the VoiceXML document. In the document there are references to audio files. It sends requests to Apache for the referenced files.
7. Apache sends a request for the file to the file system.
8. The file is read from the file system.
9. Apache responds with the requested audio files.
10. VXI puts all the audio files in the correct order and plays them back sequentially, sending the audio to the GSM dongle.

This cycle repeats until the call is terminated.

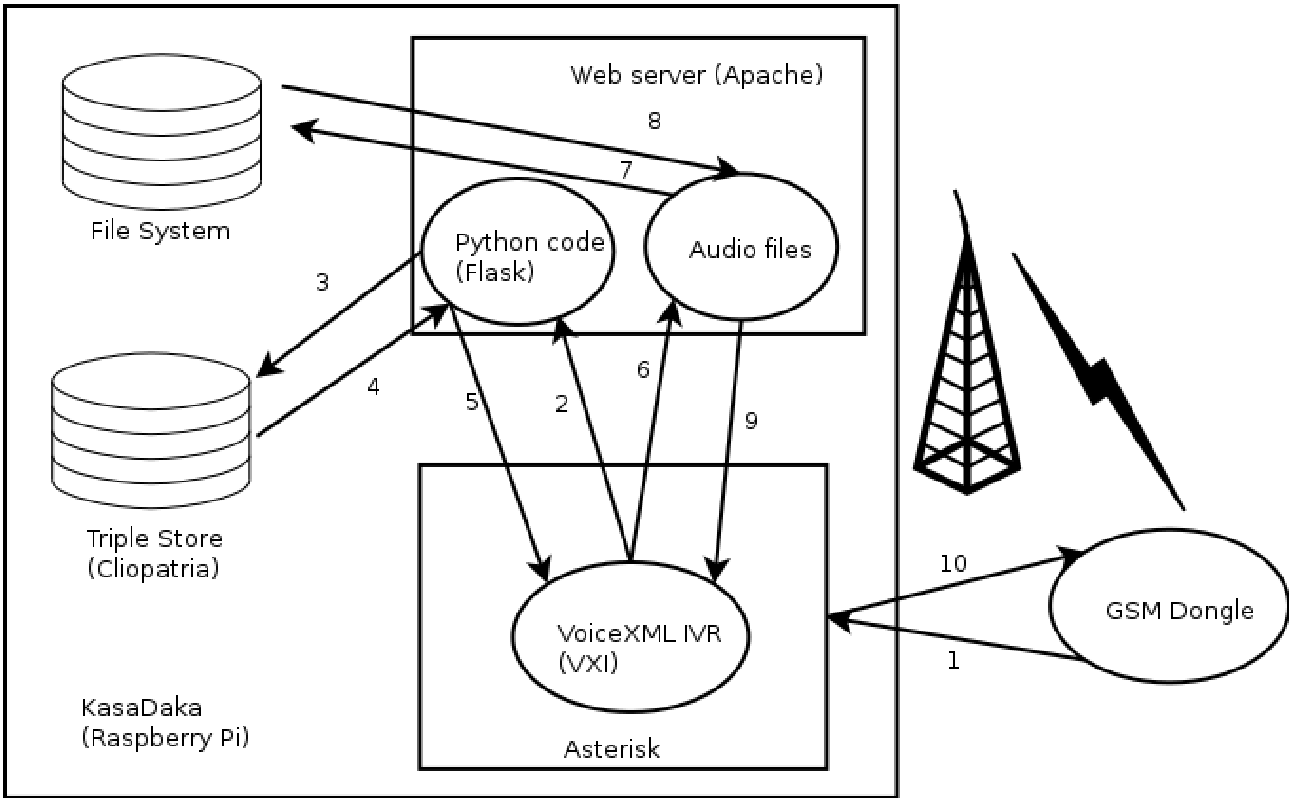

Illustration 2: The system architecture. For detailed information, consult the paper: "KasaDaka: Creating a flexible voice service framework" (2016)

Setting up a new use case

To set up a KasaDaka to run a new service (for a new use case) involves 4 steps.
First, the structure of the data stored has to be created, as well as some sample data. In our case we used a triple store, but any kind of data store can be used.
Second, the structure of the service has to be determined, and the necessary voice recordings made.
Third, (SPARQL) queries have to be written to retrieve and store the data as implemented in the structure of the call.
Finally, the (Python) code, that generates the VXML files to be used by the interpreter (and heard by the user) has to be written, incorporating the queries and structure as defined earlier.
Depending on the difficulty of the use case, as well as the skill level of the person performing these tasks, a working prototype can be made in less than an hour.

Chicken Vaccination use case (demo)
Context
Rural African farmers often have livestock (in this case chicken), these animals are often prone to disease. With proper (preventive) treatment, many diseases can be prevented or treated. This use case focuses on vaccinating livestock. For each disease that will be prevented, the proper vaccinations have to be administered at the correct time. This can usually be done by the farmers themselves. However, keeping track of the vaccination schedule is a hard task, especially when reading and writing skills are lacking.
KasaDaka
The KasaDaka will be set-up as a vaccination reminder system. The farmer will call to the KasaDaka on the day new chicken have been born. After 'declaring' the chicken, the farmer will receive calls with spoken reminders on the days that vaccinations have to be administered. An administrator can keep track of the registered farmers, and diseases/vaccinations covered by the system, etc.
Demo
The KasaDaka was called on a mobile phone, and the audience was registered as a new user. A new born chicken was declared. The administrator interface was shown, where the new data was visible and editable by the administrator. An explanation was given of the data structure used to store the relevant data in the triple store. The modular setup of the system, allowing for the extension of the system for including more languages was shown as well.

Illustration 3: Example of administrator interface

Further reading:

- KasaDaka Website: Kasadaka.com
- André Baart, Creating a flexible voice service framework for low-resource hardware: extending the KasaDaka (2016) http://www.victordeboer.com/wp-content/uploads/2016/07/abaart_thesis.pdf