Mr. Meteo: Providing Climate Information for the Unconnected

Francis Dittoh
fdittoh@uds.edu.gh
University for Development Studies
Tamale, Ghana

Victor de Boer
v.de.boer@vu.nl
Vrije Universiteit Amsterdam
Amsterdam, The Netherlands

Anna Bon
a.bon@vu.nl
Vrije Universiteit Amsterdam
Amsterdam, The Netherlands

Wendelien Tuyp
w.tuijp@vu.nl
Vrije Universiteit Amsterdam
Amsterdam, The Netherlands

André Baart
andre@andrebaart.nl
Bolesian BV
Utrecht, The Netherlands

ABSTRACT

A majority of the world remain unconnected to the World Wide Web due to issues like low literacy and relevant information. This study presents Mr. Meteo, a system that provides weather information via voice calls in local languages to rural farmers in Ghana. The study used an interdisciplinary approach to identify relevant informational needs and socio-economic implications, and early end-user and stakeholder involvement. Mr. Meteo was deployed in Bolgatanga, Ghana and represents a novel design in terms of actual web data access to rural areas. The positive feedback from farmers, and stakeholder's interest in continuity, shows this approach to be an appropriate method of development and implementation of information systems for rural areas; successful due to end-user and stakeholder involvement, focus on existing technologies, the use of voice technologies to mitigate the problem of illiteracy, and information relevance to end-users. This paper presents the methodology and results of this novel, practical, local-context ICT4D project,that has produced a viable information system for rural communities.

CCS CONCEPTS

• **Information systems** → *Multimedia content creation*; • **Hardware** → Hardware reliability; • **Software and its engineering** → **Software development methods**; **Software prototyping**; Collaboration in software development;

KEYWORDS

Web Access, Digital Divide, Interdisciplinarity, Literacy, Voice Technologies, Climate Change, Sub-Saharan Africa

ACM Reference Format:
Francis Dittoh, Victor de Boer, Anna Bon, Wendelien Tuyp, and André Baart. 2020. Mr. Meteo: Providing Climate Information for the Unconnected. In *12th ACM Conference on Web Science (WebSci '20 Companion), July 6–10, 2020, Southampton, United Kingdom.* ACM, New York, NY, USA, 6 pages. https://doi.org/10.1145/3394332.3402824

WebSci '20 Companion, July 6–10, 2020, Southampton, United Kingdom

ACM ISBN 978-1-4503-7994-6/20/07…$15.00
https://doi.org/10.1145/3394332.3402824

1 INTRODUCTION

1.1 Digital Divide

In the past 28 years, the World Wide Web has greatly changed the way the world communicates and has metamorphosized the various aspects of life that are directly or remotely connected to it. The concept of a global village has been aided by the effective communication and access to information that the World Wide Web has provided. The problem remains however, that a large population of the world remain unconnected to the World Wide Web (even remotely). A United Nations report [1] in 2017 shows that of the 7.6 billion people in the world, 3.58 billion (48%) are using the internet. Admittedly, this is a step up from the previous year's value of 45.9 percent, however, certain regions retain very high numbers of unconnected. Only 39.4% of Africans are connected to the internet; meaning about 800 Million Africans have no internet access. In addition, there is an added disparity in gender access in developing countries, especially Africa [15]. The reasons;

1.1.1 Lack of Infrastructure. The lack of adequate infrastructure in Sub-Saharan African countries plays a major role in the issue of connectivity for the unconnected. Admittedly, some systems exist and work well to some extent in certain countries, however, there is an internal urban-rural divide which means even further deterioration of services in the rural areas [3]. This is clearly seen in the areas of electricity and internet connectivity which are less available and reliable in rural communities as opposed to urban communities [4].

1.1.2 Affordability. Regardless of infrastructural problems, there are systems that work and are available, if not fully reliable. In Ghana, voice and internet services have national-wide coverage [5], but the cost of hardware required to access some of these services (mainly internet) and the cost of services, remain unaffordable to many in both rural and urban areas. As such, these technically feasible services remain financially unfeasible [4].

1.1.3 Literacy. The issue of literacy remains a barrier to the delivery of information in the current World Wide Web formats. Ghana has a literacy rate of 76.67% [1]. However, the rural north, which happens to be a major food source for the country, has its literacy rate lower than 30% [2][6]. Currently 80 percent of online content is available in only 10 languages, which only around 3 billion people

[1]https://data.worldbank.org/
[2]https://uil.unesco.org/

speak as their first language [7]. In addition, information available online is heavily biased towards text and thereby discriminates against those who cannot read and write [4].

1.1.4 Relevant Content. The literate, avid internet user does not require (and mostly does not seek out) random information that is irrelevant to their livelihood. A major barrier to connecting the unconnected has been that they do not find the information, even if available, to be locally relevant enough to warrant the effort to gain access to it [2]. The availability of information relevant to the livelihood of the end-user is a viable incentive to get connected.

1.2 Climate Change

An example of possible relevant information is climate and weather information. This is because there has been overwhelming evidence of climate change in recent years; increasing global temperatures, rising sea levels, increased ocean acidity and increase in extreme natural events are but a few obvious indicators [8]. Moreover, local farmers are aware of climate change and have attested to the need for modern scientific knowledge to augment their indigenous climate knowledge [9]. In Ghana, fairly accurate seasonal (regional) rainfall forecast is available from the National Meteorological Services [3] mostly online and during Television Weather Reports (in English). Less accurate, but usable daily and weekly local forecasts are also available through a combination of satellite data and local weather stations which feed open weather sources online. This information however, hardly ever reaches rural farmers.

1.3 ICT4D 3.0

Developing ICT systems in low-resource environments requires a vastly different approach from the methodology utilized in high-resource environments. Known issues (see Section 1.1, 1.2) combined with unknown contextual issues regularly result in unsuccessful ICT4D deployments. Design shortcomings in numerous ICT4D systems leads to delays, high rates of project extension and restructuring, and high failure rates [10]. This study presents a novel, practical, on-the-ground application of an iterative, adaptive and collaborative field research methodology (dubbed ICT4D 3.0) [4].

2 PURPOSE OF STUDY

We know ICTs can make an impact in access to information [2], however, clear cases of development methodologies are still lacking. The purpose of this study is to do exactly that; implementing an earlier developed methodology (ICT4D 3.0) [4] in a case study.

This research answers the question of how ICTs can provide rural communities in developing countries with regular access to up-to-date information, from the world wide web, peers or organizations?

- Considering the level of infrastructure in these rural areas, what ICTs are feasible and what are the implications of the disruption that may result from the introduction of these technologies?
- How can we technically influence affordability and financial sustainability of the system?
- What are the methods of determining relevant information for these communities?
- What measures can be taken to circumvent the issue of illiteracy in the delivery of information?
- How can these systems be maintained and further developed within the local context?

These questions are answered by presenting a novel, practical, real-world, local-context use of appropriate ICT4D methodology, that has produced a viable information delivery system for rural communities.

3 METHODOLOGY

This study used a collaborative, adaptive and iterative methodology (see Figure 1) to identify and tackle the issues from a socio-technical standpoint [4]. The methodology works iteratively to gain an in-depth understanding of the context from the end-user and stakeholder perspective, elicit and assess their needs vis-a-vis the available technologies and possible ICT solutions, build a specific use-case with its functional and non-functional requirements, assess the financial sustainability of the project with design adaptations (where possible) to mitigate any financial issues, and finally build and deploy with evaluations that are iterative.

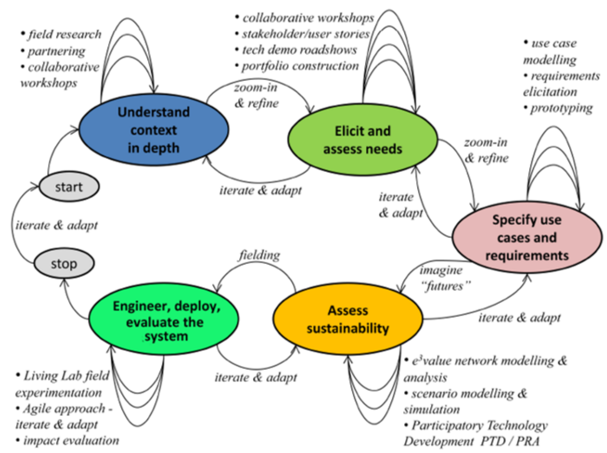

Figure 1: ICT4D Methodology [4]

3.1 Research Area

The research focuses on Northern Ghana which covers about 40% (97,000Km2) of the nation's surface area). It has a total population of 5 Million and by contrast has a far lower literacy rate compared to the national rate (see Section 1.1.3). This area is selected for our case studies because its rural areas fit the targeted group; being an agriculture-production region, having impact on the nation's food security, but being more deprived of infrastructure, and with higher illiteracy rates.

3.2 Context Analysis and Needs Assessment

3.2.1 An Interdisciplinary Approach. Contextual information was initially obtained from a collaborative workshop, ICT for Food and

[3] https://www.meteo.gov.gh/gmet/

Water in Ghana - Collaborative Research by VUA and UDS , which was organized in Walewale, Ghana by Vrije Universiteit's Web Alliance for Regreening Africa (W4RA) team, together with a team of researchers from the University for Development Studies, Tamale, Ghana. The team consisted of a multi-disciplinary group of experts in rural economics, animal science, tropical agronomy, irrigation, microfinance, sustainable land management, gender, value chain development and ICT4D. With some existing work (notably among these being the Digivet Animal-Health Application [11]) as guidelines, the workshop brainstormed around the various technological possibilities for information delivery systems related to food and water security. Subsequently, the Savanna Agricultural Research Institute (SARI), located in Tamale, Ghana, which is working directly with local farmers in the region, provided further insight in the areas of meteorology; the local outlook and understanding of climatic conditions, and communication; language and information dissemination in the local context.

3.2.2 An adapted Living Labs Approach. The above-mentioned workshop in Walewale, Ghana, which formed the starting point of this study, took on an adapted Living Labs approach and accordingly included end-user involvement from the get-go. Workshop participants visited Guabuliga, east of Walewale, a community of about 2000 inhabitants who live from rain-fed agriculture and livestock, where the discussion continued with the inclusion of 50 to 60 members of the community. The idea of the Mr. Meteo application originated from the rural community during this focus group discussion. Upon giving a general overview of the possibility of information being sent to them, climate information was mentioned specifically and they indicated that this was because climatic conditions had changed from the norm over the years. Subsequently, climate information had been a recurring theme in most communities thus leading to the creation of Mr. Meteo as a use case for providing information to the unconnected.

3.3 Use-Case and Requirement Analysis

As an understanding of the context began to form, the authors began to elicit stakeholders and end-users on the needs of the system, in an iterative fashion. An assessment of the local infrastructure, by field visits and interviews with SARI and other organization, pointed to the unavailability and/or unreliability of certain ICTs that could have been in consideration. Internet access in the rural areas of the northern sector of Ghana were found to be unreliable at best and often slow or unavailable. In contrast, mobile telephony and radio reception was found to be available and more reliable. In addition, all end-users owned or had access to a mobile phone (Ghana has a mobile penetration of 130.9%, [12] owing to the fact that a sizable number of people have more that one phone or use multiple sims on one phone). Other research has found very little to no use of SMS and little to no use of smartphones in the rural areas of northern Ghana [6]. These findings have been further verified during this study. Further assessment of the issue of literacy revealed that, end-users would be open to voice-based information delivered in their own local languages.

3.3.1 Key Idea. An analysis of the above resulted in fine-tuned key idea - To build a system that provides weather information via voice prompts in local languages over voice calls to rural communities in northern Ghana. Members of rural communities will be able to call in to a local mobile number, upon which the system will answer and read out the weather forecast in their own local language (see Figure 2).

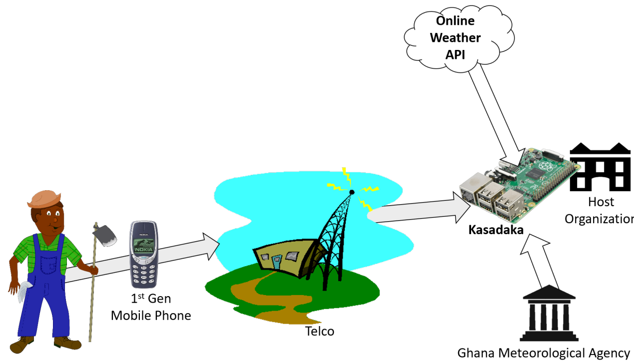

Figure 2: Sketch of Intended System

3.3.2 Actors and Goals.

ID	Actor	Description
1	User	Call phone number to get weather forecast
2	Weather Source	Relay Weather Forecasts
3	NGO/Company	Manage Users
4	NGO/Company	Record Voice Fragments for new languages
5	Support	Monitor system; maintenance

3.3.3 Key Requirements. Following information obtained from rural communities as well as considering the technologies available, the following are the key requirements of the system;

Must Have

- Weather forecast source
- Interactive Voice Response (IVR)
- Local Language(s)
- Regular Weather Updates
- Storm Alerts

Should Have

- Temperature data
- Wind speed data

Could Have

- Subscription-based service
- Short-Range Radio (FM) Transmission of information

3.3.4 Non-Functional Requirements.

- Maintainability - Local developers should have the ability to maintain, adapt and replicate the system with relative ease.
- Availability - Users must have the ability to reach the system. As such, barring mobile network issues, the system must be hosted on a platform that will be available at all times.
- Scalability - The system must have the ability to scale to different locations and for any number of subscribers.

- Reliability - The system must ensure that forecasts are as accurate as possible.
- Usability - The targeted user group creates a requirement of simplicity in the user interface
- Cost-Effectiveness - The whole system must work together to be financially sustainable

3.4 Feasibility and Sustainability Assessment

The feasibility and sustainability of the system is assessed by considering the technical and business/socio-economic feasibility as well as possible goal conflicts, dependencies and preconditions required for the system to function as a whole [4]. These issues were discussed in interviews with stakeholders at various levels of the study. Technically, the simplistic nature of the design makes Mr. Meteo feasible. The design focuses on affordable hardware, open-source software and does not require additional technical purchases and/or skills from the end-users. Socio-economically, discussions with stakeholders has shown that effective information flow, to and from rural communities has been an ongoing struggle and therefore this provides them with a way of not only saving time, but also delivering information they would have hitherto not been able to. Grandiose systems, like large radio transmitters, often become a financial sink and render most deployments financially unsustainable. Mr. Meteo therefore uses low-cost hardware and open-source software (see Section 3.5.1). Preconditions for the system to work include hosting capabilities required from stakeholders. These capabilities include basically power supply, internet access and access to local telephone network. The end-users are required to have a mobile phone. These preconditions and all dependencies were met and there were no goal conflicts.

3.5 Development and Testing

Figure 3: Kasadaka Hardware

3.5.1 Kasadaka. Mr. Meteo is built on the Kasadaka Platform [13] [14]. The Kasadaka ("talking box" in a number of Ghanaian languages), enables the development and hosting of voice-based information services, targeted at rural sub-Saharan communities. The hardware and software of the platform are catered to the specific contextual requirements as found in these areas. The hardware forming the foundation of the KasaDaka platform is the Raspberry Pi (see Figure 3), which is a low-resource computer based on an ARM processor. The Raspberry Pi runs a Debian-based Linux distribution. To provide the Raspberry Pi with connectivity to the local mobile phone network, a USB 3G modem is used. The total costs of the hardware is around $70. The Kasadaka runs a stack of applications that provide the different functions that are required for voice-based interactions. Asterisk, an open-source telephony exchange application is used in conjunction with chan_dongle (an interface to phone modems) and VXI (a VoiceXML interpreter), to provide the voice-based interactions through the local GSM network. [13]

3.5.2 Development and Testing. The system was built on the Kasadaka in Tamale, Ghana in collaboration with Cowtribe [4], a company that provides veterinary services with the use of ICT-driven technologies. Audio fragments were recorded locally (in Gurune, the

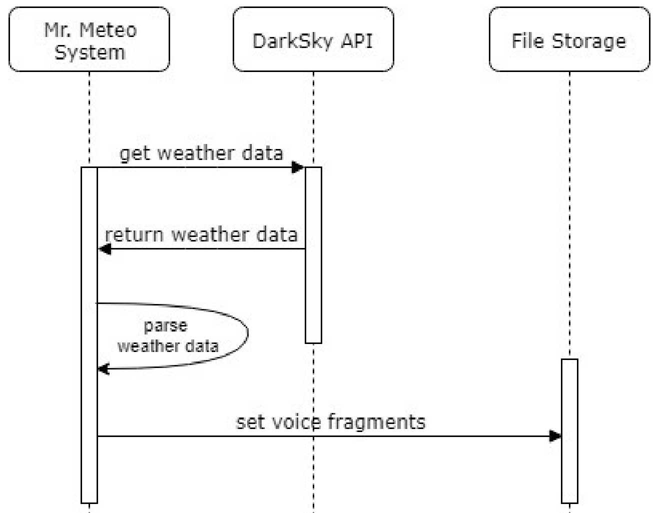

Figure 4: UML Sequence Diagram - Weather Information Update

major language in Bolgatanga, Ghana, for which no Text-to-Speech (TTS) nor Automatic Speech Recognition (ASR) exists), and sent to Tamale where it was converted to the appropriate formats and integrated into Kasadaka. Fragments to support an additional language (Dagbani, also with no TTS and ASR) were recorded in Tamale, to provide a control test case and proof of scalability in terms of language. The structure of the Mr. Meteo application is set up in a way that welcomes the user to the service and then proceeds to the weather forecast for the current day as well as the subsequent day. A total of roughly 5 hours (excluding the time for recording voice fragments) was needed to completely setup the system. The resulting system was deployed and evaluated in several iterations, using a local Ghanaian Network Provider (MTN) and soliciting feedback from Cowtribe, SARI and selected participants. The system is setup to retrieve data (see Figure 4) from Darksky Weather API[5] for the specific GPS Coordinates (retrieved at the community and verified on Google Maps). Parsing of the data indicates which

[4]https://www.cowtribe.com/
[5]https://darksky.net/

voice fragments should be accessed during calls into the system. When a user calls in (see Figure 5), Mr. Meteo automatically picks the call and immediately plays a welcome message followed by the predetermined voice fragments. To aid simplicity and in accordance with the particular context, user input is not required for receiving weather information (e.g. for language selection), since all callers to the specific system speak the same language.

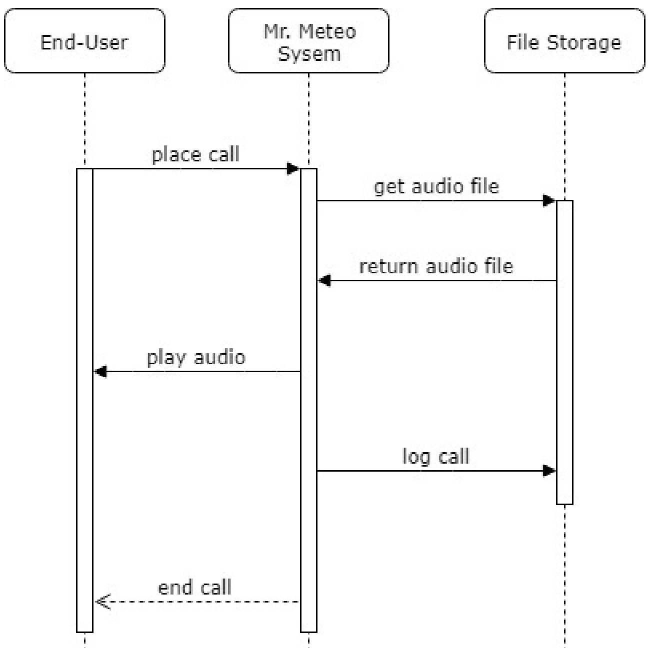

Figure 5: UML Sequence Diagram - Call Management

3.5.3 Challenges. Internet access, which is not always available and reliable was sometimes an issue during testing and could be a challenge with subsequent regular use by end-users. A solution to mitigate this was to always retrieve a 7-day forecast (the system provides end-users with a 2-day forecast). This provides a backlog of data in the event the system is unable to reach the internet. Future plans to solve this challenge also include working on alternative means of data transfer to the Kasadaka (e.g. SMS). A major challenge faced involved the availability and readiness of stakeholders and organizations for field tests, workshops and interviews. Budget cuts, unforeseen changes in planning and busy schedules were among the few barriers faced by stakeholders and organizations that contributed to a slower development cycle than expected. A solution to this challenge in this study was to collaborate with a number of stakeholders so as to enable continued work in the event that any organizations had setbacks.

4 DEPLOYMENT AND RESULTS

Mr. Meteo was piloted to a group of 50 farmers from 4 communities in Bolgatanga in the Upper East Region of Ghana in collaboration with Cowtribe during one of their regular field visits. Due to the wide distances between communities, Cowtribe collaborated with partners in Bolgatanga to have farmers transported to a central location from the 4 communities. Farmers came along with their animals for veterinary tagging. The study used a semi-structured focus group discussion before and after the introduction of the system. It was found that 100% of farmers owned their own mobile phones and used them regularly to make calls of which more than 50% were said to be related to farming and livelihood. In contrast, none of the farmers used the SMS features on their phones, although they are all aware of the function. Additionally, all farmers owned (or has access to) a radio set. Farmers needed little introduction to the system, since Cowtribe has existing mobile-based communication systems for farmers albeit manual and expensive to maintain, and more importantly, farmers' view were previously solicited during the design phase. Farmers tested the system by calling into the phone number; those who did not call personally, listened in on others' calls. A focus group discussion and some individual interviews with farmers and members of Cowtribe was held afterwards to ascertain the success of the pilot and to receive feedback on usability and any possible concerns.

4.1 General Impressions

Due to the methodology used in this study (which involved end-users and stakeholders), it was expected that the general impression of the finished system would be positive. This was the case, with there being enthusiastic reception of Mr. Meteo by both farmer and stakeholders.

4.2 Stakeholders Perspective

Cowtribe found the system to be "innovative and needed". The company was eager during the development period and contributed immensely to its success. Cowtribe is also eager to scale up the system in terms of additional languages for other communities, other relevant content (being a veterinary-centered company, they are also interested in information pertaining to animal health) and a future plugin system related to community (Ham) radio transmission (see Section 6).

4.3 Farmers Perspective

100% of farmers gave positive feedback on what they thought of Mr. Meteo. Most considered the system to be "good" and "helpful" and at least 90% indicated that it is a system they would use regularly with the rest indicating that they would be less inclined to use it during the middle of the dry season, but more towards the end (to know when the rains would start) and during the rainy season (as expected; to know the trend of the rains). In terms of cost implications, about 90% of farmers interviewed are willing and able to make calls into the system to retrieve weather information, however a few showed reluctance due to the cost of calling in. Furthermore, some farmers suggested a subscription-based service. Farmers also indicated that they would also be interested in information like disease outbreaks, human and animal health, farming practices and information on their children's schooling.

5 CONCLUSION

5.1 Infrastructure

Infrastructure in the rural areas of Ghana are lacking, but there are ICTs that are available, reliable and in use; namely radio and mobile telephony. This study focused on these available technologies as opposed to the introduction of new infrastructure which results in expensive and extremely disruptive implementations. The focus on technologies already in use resulted in lower cost of implementation and being more acceptable by the rural farmers.

5.2 Affordability

In addition, the study utilized the Kasadaka; low-cost hardware with open-source software, to implement the system. This resulted in a low-cost system that was feasible to deploy and will be financially sustainable in terms of maintenance and usage costs. Cowtribe and SARI are interested in scaling up of the system, and this is partially due to the fact that scalability has been made feasible due to the affordability of the hardware and low running costs.

5.3 Relevant Information

Determining relevant information for dissemination can be erroneously assumed to be trivial. Lessons from this study shows that an iterative, adaptive and collaborative field research methodology with early involvement of end-users provides a great determinant of what information may be deemed relevant to rural communities. Stakeholders indicated that adoption of these systems by the end-users can rely heavily on this and as such, as learnt from this study, should be considered a top priority.

5.4 Literacy

With regards to illiteracy, the study found the use of text-based systems not feasible in the context of rural northern Ghana, where people are unable to read and write. The ready adoption of mobile telephony and the pre-existing oral-based communication culture informed the use of a voice-based system. The added value of utilizing local languages merged to circumvent the issue to illiteracy. Granted, this presented an increased complexity due to the need of translations and language recordings, which is not always trivial; technical words and numbering systems are often somewhat problematic to handle although feasible in the long run.

6 FUTURE WORK

The continued development and scaling up of Mr. Meteo are considered imperative for all stakeholders. In the spirit of the iterative nature of our design methodology, the results of this study will form the basis for further development. In collaboration with Cowtribe and SARI, the current system will be expanded in terms of language and reach. Additional hardware will be procured to enable the system reach more communities and also deployed to regions that speak other languages. In addition, Cowtribe will like to explore the build of a system around the same design to, alongside climate information, facilitate the dissemination of veterinary-based information to aid animal farmers in rural communities. Another future modification is the transmission of pre-recorded audio over FM frequency using the Raspberry Pi. The general concept is to setup a device within a community, utilize Kasadaka to call as admin and leave recorded messages which the system will then transmit over a pre-determined FM frequency. This will be useful for delivering variable information which may have been hitherto cumbersome to create pre-existing voice fragments for (e.g. Mr. Meteo - Seasonal Forecasts, Disease Outbreaks, Other alerts) In addition, use cases that only require concatenation of pre-existing voice fragments (e.g. Mr. Meteo -Daily Updates) can also be triggered by SMS containing code for the required concatenation. This implementation (dubbed RadioNet) has already taken place in conjunction with SARI and The Internet Society [6]

ACKNOWLEDGMENTS

The authors thank Christophe Guéret for the original Kasadaka idea and the University for Development Studies' team led by Saa Dittoh. We also acknowledge the contributions of Kay Kutah Wilhelm (SARI) and the co-founders of Cowtribe. The authors also thank Hans Akkermans, Chris van Aart, Amadou Tangara, Chris Reij, Stephane Boyera, Gossa Lô, Julien Ouedraogo, Matthieu Ouedraogo, Mary Allen, Nana Baah Gyan, Aman Grewal, Yacouba Sawadogo, Stefan Schlobach and many others for their contribution to this continuing research project.

REFERENCES

[1] ITU; UNESCO, "The State of Broadband 2017: Broadband Catalyzing Sustainale Development," Broadband Commission for Sustainable Development, 2017.

[2] S. Schmida, J. Bernard, T. Zakaras, C. Lovegrove and C. Swingle, "Connecting the Next Four Billion: Strengthening the Global Response for Universal Internet Access," USAID, Dial, SSG Advisors, Seattle, 2017.

[3] A. Estache and M. Vagliasindi, "Infrastructure for accelerated growth in Ghana: Investment needs,Policies and Institutions," World Bank, 2007.

[4] A. Bon, H. Akkermans and J. Gordijn, "Developing ICT Services in a Low-Resource Development Context," Complex Systems Informatics and Modeling Quarterly, pp. 84-109, 2016.

[5] I. Fosu, "Exploring the potential of wireless technologies to accelerate universal Internet access in Ghana," Telecommunications Policy 35, pp. 494-504, 2011.

[6] F. Dittoh, C. van Aart and V. de Boer, "Voice-based marketing for agricultural products: a case study in rural Northern Ghana," in Sixth International Conference on Information and Communications Technologies and Development, New York, 2013.

[7] E. Luxton, "4 billion people still don't have internet access. Here's how to connect them," World Economic Forum, 2016.

[8] J. Lewis, "The Science of Climate Change: Evidence, Examples, and Avoiding the Worst," 2007. [Online]. Available: https://www.rdn.bc.ca/cms/wpattachments/wpID3296atID6572.pdf.

[9] H. Mahoo, W. Mbungu, I. Yonah, J. Recha, M. Radeny, P. Kimeli and J. Kinyangi, "Integrating Indigenous Knowledge with Scientific Seasonal Forecasts for Climate Risk Management in Lushoto District in Tanzania," CGIAR Research Program on Climate Change, Agriculture and, Copenhagen, 2015.

[10] Independent Evaluation Group (IEG), "Capturing Technology for Development: An Evaluation of World Bank," The World Bank Group, Washington, 2011.

[11] G. Lô and R. Blankendaal, "DigiVet, Knowledge Engineering an Animal Health System for Farmers in Northern Ghana," Vrije Universiteit Amsterdam, 2016.

[12] N. C. Authority, "Quarterly Statistical Bulletin on Communications in Ghana," Communications for Development, Accra, 2017.

[13] A. Baart, A. Bon, V. De Boer, W. Tuyp and H. Akkermans, "Kasadaka: A voice service development platform to bridge the web's digital divide," in Proceedings of the 5th International Symposium "Perspectives on ICT4D" co-located with 10th ACM Web Science Conference (WebSci'18), Amsterdam, 2018.

[14] A. Baart, A. Bon, V. De Boer, W. Tuyp and H. Akkermans, "Ney Yibeogo - Hello World: A Voice Service Development Platform to Bridge the Web's Digital Divide," in 14th International Conference on Web Information Systems and Technologies, Seville, 2018.

[15] Gillwald, Alison, Anne Milek, and Christoph Stork. "Gender assessment of ICT access and usage in Africa." Towards Evidence-based ICT Policy and Regulation 1, no. 5 (2010).

[6] https://www.internetsociety.org/