Message Phone: A User Study and Analysis of Asynchronous Messaging in Rural Uganda

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***Abstract*—We explore the value and utility of voice messages for cellular users that live in areas of poor or intermittent network coverage. Voice messages have the potential to be much lower cost than traditional live calls and should work well in areas of intermittent coverage. To explore these questions, we built a prototype cellphone system with voice messaging capability, performed trials with rural Ugandan users, and then conducted focus group discussions to understand their reactions.**

Overall, we interviewed 230 participants in ten villages of varying connectivity. We found that voice messages were quite popular and uniformly preferred over text messages (SMS) due to their ease of use and the richness of voice. We also found that voice messages can mitigate the problems of intermittent connectivity. Finally, we found that, assuming lower cost for messages than live calls, users would use voice messages frequently (more than they currently use SMS), but that they would still prefer live calls in some situations. Based on these results, we believe that voice messages are an important capability to add to cellular networks in emerging regions, especially for users that live in areas of poor coverage.

I. Introduction

Mobile phone coverage and ownership has grown at an extraordinary rate, in both the developed and the developing world. India and China have seen enormous growth to hundreds of millions of users. Africa has seen penetration grow to 9-10%, and worldwide users have already reached 3 billion [1]. There remains, however, a significant percentage of the world's population that will be left out of this expansion.

Although coverage areas are growing, infrastructure providers naturally focus on areas with high population density, which amortizes the high costs of base stations. Even Grameen Telecom in "rural" Bangladesh depends on high population density for economic viability. Also, in these areas, transportation and power infrastructure tend to be better maintained than in rural areas, and trained engineers are closer at hand. These factors, and many others, all create an economic environment in which telecom providers shy away from rural and semi-rural areas in favor of more lucrative, albeit more competitive, urban markets.

Even in highly competitive urban markets, the cost of building and maintaining telecom infrastructure (and often the accompanying power and transportation infrastructure) in a developing country leads to airtime charges often in excess of US$0.10/min. In Uganda, where this study took place, the rate is about US$0.20/min. We believe that this is due to fundamental costs associated with the need to provision resources for live calls.

Earlier, we proposed the idea of using the mobile phone primarily as a voice-message device [2]. Focusing on asynchronous rather than synchronous (e.g. real-time) communication has the potential to reduce the cost of infrastructure by an order of magnitude in new deployments, as well as to extend the reach of the mobile phone network to areas with unreliable coverage. All of this can be done with changes only to provider's pricing models and client handsets. However, as it was a proposal, our work did not provide an implementation and did not investigate how users would react. In addition, our proposal used data from the urban USA [3], which possibly does not represent connectivity in rural Africa.

Our new contribution is to implement a basic voice-messaging phone and explore its value to Ugandan users via trial deployments and interviews. To begin to investigate how users would react to such a system, we conducted a trial deployment in July and August of 2008 in rural areas of Uganda. This project included focus groups with approximately 230 individuals in ten different villages.

Our study focused on identifying the primary user needs and concerns with a message-oriented phone system. In addition to confirming users' high sensitivity to cost, we also confirmed people's willingness to expend significant effort to communicate, their frustrations with the limitations of SMS, most users' preference for voice communication, and their use of asynchronous communication mechanisms when they are available. We also found that message-only phones do not appeal to users. Thus, voice messages are better viewed as a replacement for SMS. Our study did not attempt to address carrier issues such as cost structure or extended coverage in depth.

We outline the basic arguments in favor of voice messages in Section II and then present our implementation in Section III. Sections IV and V present the methodology and results of our study. We end with related and future work and a summary of our conclusions.

II. The Value of Voice Messaging

In this section, we summarize the potential network advantages of the voice-messaging model as described in our original proposal [2]. Briefly, the potential advantages are: better resource utilization, increased effective coverage area, and better perception of service. Obviously, these benefits all impact the cost to the user in one way or another. For a more in-depth analysis please see the referenced paper.

A. Better resource utilization

The resources of a synchronous communication system are idle most of the time. This is due to the resources required for synchronous communication, which must be provided exactly when needed. Asynchronous communications improve this situation by allowing for load balancing, moving messages to times when the system is under-utilized.

Peak usage in an earlier study conducted by MIT researchers [3] was around an order of magnitude higher than average usage. In Figure 1, the Peak-to-Average ratio is shown, where the average is over the duration of the study. Users operated on average at about 3% of their peak utilization, and in the busiest hour of the study, they operated at about 50% of the peak. Voice messages fit within the gaps of the synchronous service, and hence should have zero marginal cost, as even the transmission power is typically at maximum in these gaps.

B. Increased effective coverage

Perhaps surprisingly, in cases of poor coverage, moving to an asynchronous model can in fact *improve* delivery latency. This is because in areas of poor coverage, the probability that both the sender and the recipient are in network range simultaneously is low. Our user study partially confirms this. We found that Ugandan users would intentionally use SMS when they expected the receiver to be in poor connectivity.

C. Better perception of service

Based on data from Ghana, we found that most outages are fairly short in duration and can therefore be masked from the end user in an asynchronous system, unlike live calls. Thus, voice messages should have a higher real and perceived uptime; the uptime seen by a voice message user depends on the caching and timeout behavior of their handset and not as much on the infrastructure.

III. Design and Implementation

The primary purpose our prototype is to enable a realistic voice-messaging experience for the Ugandan users in our study, so that we can gain accurate reactions to the value and usability of the technology. Toward that end, our prototype, called the *mPhone*, sends and receives voice and text messages and even makes live calls. It runs on a wireless handset that is essentially a cell phone.

We begin with a discussion of lessons learned during the implementation process, then follow with a description of the prototype.

A. Lessons Learned

We began the implementation believing that we needed to modify a GSM base station to gain the benefits of asynchronous messages. The modifications would allow for mPhone messages to be sent at a lower priority than other message schemes. This turns out to be false.

It is the case that both MMS and GPRS connections are already scheduled at a lower priority than direct call traffic. Most low-end cellular phones do not utilize this fact, forcing users to send SMS and MMS messages immediately.

This is a huge advantage. Providers need only modify their pricing schemes, rather than their scheduling algorithms. MMS and GPRS traffic is highly priced, as the majority of users of these technologies in the developing world are wealthy. mPhone messages using either MMS or GPRS as the transport would need to be priced at a more affordable rate. This is the only change required to providers' towers.

Lastly, we were unsure about how to port our application to lower end phones. Our networking layer used state of the art networking technologies and porting those would have been exceedingly difficult. However, we discovered that MMS would allow for an easy store-and-forward layer. As such, we have already ported our application to the Symbian OS and continue to target lower-end phones for mPhone.

B. mPhone Implementation

mPhone leverages previous work in Delay-Tolerant Networking (DTN) [4]. The DTN system is used on both the handsets and server. DTN simplifies asynchronous communication by handling the management of connections and movement of data in the background. DTN allows for message transmissions from handset to handset even if there is no time in which an end-to-end connection exists.

For our delay tolerance, we use the DTN research group reference implementation [5]. We use this system to send voice and text to users, as well as allowing users to send messages to email addresses and traditional telephone users. As our system utilized DTN over IP (WiFi or GPRS), we were forced to implement a simple router to direct messages to the appropriate phones via the DTN Layer.

Our system consists of two parts: The handset client and DTN router. We also implemented an Asterisk [6] PBX to interface our message system with existing low-end phones, but it was not used during the study.

1) Handsets: Through a generous donation from Nokia, our handset hardware consists of eleven Nokia N800 and N810 Linux tablets. These are not technically cell phones, but have mechanisms for recording and playing audio. They are more powerful than cellphones, so they provide a fine prototyping platform. They also have the same form-factor as cellular phones, and are often used for Voice over IP communications. We have written a client for the Symbian S60 operating system, which supports much cheaper handsets. However, this was unavailable in time for the study.

The handset software is very simple. Its basic functionality is to send and receive packetized audio and textual communications over DTN. This is done in the obvious manner, with the user either recording or writing the message to be sent. The application then packages it with metadata and sends it to the server using the DTN libraries. Users can create and listen to messages while disconnected.

We built our system to support exploration of different pricing schemes. It is possible to bill the user on a per-second, per-minute, or per-message basis. This is configured at the

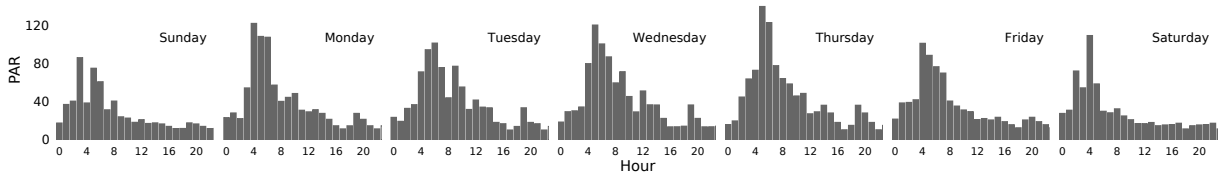

Fig. 1. The Peak-to-Average Ratio (PAR) of calls in the MIT study [3], grouped by hour of the day. Only about about one hour every two days had a PAR less than 4, and the overall PAR for the entire study was 35.6, showing the large amount of unused system capacity.

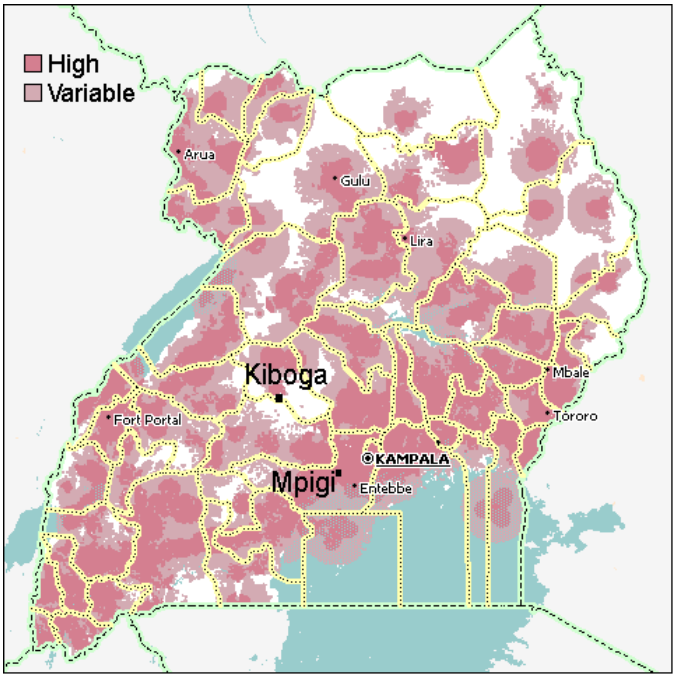

Fig. 2. Map of MTN Uganda's GSM coverage [7] and the locations of our two research hubs, Kiboga and Mpigi.

server. We did not require payment from users in the trials, but they were able to understand relative costs from this interface. In general, the device felt like a prepaid phone with credit decreasing when used.

2) DTN Router: We emulated a cellular network using a WiFi access point, as the handsets support WiFi. Data bundles (text or audio) were forwarded using DTN to the router, which then mapped from the handset's "phone number" to its DTN address. The packet then eventually arrived at the handset. A network provider would not need to use the router if it used a transport with an existing routing solution, such as MMS.

IV. Study Design

The goals of our study in Uganda were to explore the accessibility and value of voice messages to rural Ugandan users, and to survey users in both rural and semi-rural areas about their communication habits.

A. Strategy

We chose rural Uganda as the site of our studies because GSM coverage maps show large areas with limited and missing coverage [7]. Figure 2 shows a coverage map for the MTN Uganda network along with our two primary research areas, Kiboga and Mpigi. These sites also border large trading areas, which simplified travel and access to the research sites.

We decided to study both users in areas with intermittent or poor connectivity and also in areas with no connectivity. We wanted to determine how users deal with intermittency in areas that have network coverage, but often lose it. We also wanted to understand the needs and behaviors of people who live in areas with no coverage, particularly those who live *near* an area with coverage.

The majority of Uganda is covered by wireless networks, but the stability of this coverage varies. Power issues, weather, and innumerable other concerns cause the network to become unavailable. For users affected by the network intermittency, we wished to discover what, if any, solutions they have for this, and whether or not voice messages might mitigate these problems. We expected that mPhone's asynchronous communication scheme would allow them to communicate effectively even during periods of high intermittency.

Large swathes of Uganda have no network coverage at all. The majority of these areas are in the north, which have security concerns that limit research opportunities. However, even in network covered areas, there exist valleys where the network fails. For these areas, we aimed to determine the feasibility of the mPhone as a primary communication method. If there existed a low-cost GSM tower that did only asynchronous communication, would this benefit the people in these areas? We also wished to discover how villagers in these areas communicated and how this could be made easier by the mPhone application.

There were some questions that applied to all areas. We wanted to explore basic properties of the usability of a voice-message system for low-literacy users. We also hoped to discover how their cost sensitivity affects pricing for message-based communication. For instance, direct calls in Uganda can be priced at either per-second or per-minute rates, whereas SMS is only priced per-message.

B. Study Format

Our studies were run as focus groups. Local assistants translated the discussions, while we gathered field notes and video. To locate test subjects, we first scouted for areas filling either of the two categories, intermittent or lacking coverage, and scheduled a time when a group of villagers would be willing to meet and assist us in our study. We arrived at that time and distributed the handsets to the villagers. As this was

a limited deployment of the technology, the phones are able to communicate only with other local mPhones. We demoed the application and had them use it until they were comfortable. This involved recording and sending messages to other users nearby. Users also received messages, and had short back-and-forth conversations. We then began a discussion with the goal of answering our research questions.

We ran our study throughout the months of July and August in trading areas surrounding Kampala, the capitol of Uganda. Our first hub was Mpigi, a trading area around one hour west of Kampala. Mpigi is very rural, with only 8.4% of the population living in urban areas [8]. Mpigi is shown on the GSM coverage map, Figure 2, to have widespread coverage. From this area, we found three villages with intermittent coverage, and one village with no coverage at all.

Our second hub was in Kiboga, a town three hours north of Kampala. This town is on the border of the GSM coverage according to the map. Here, we visited five intermittent connectivity villages and one disconnected village. Each village had ten to thirty participants.

Overall, we visited ten villages with an aggregate reach of 230 users trying the system and participating in interviews.

V. Results

There were a number of findings from our study in rural Uganda. We've organized our findings into three distinct areas:

- Cost: We discovered that the users were extremely price sensitive, motivating their use of message systems.
- Accessibility: We found that the existing message systems are very difficult to use, with most users greatly preferring to use direct calls. Voice messages, however, were easier to use.
- Applicability: The users in rural Uganda have many network difficulties, which they are currently unable to deal with effectively.

We provide an overall comparison afterward, which found that users would greatly prefer voice messages over existing text-messaging systems, but also want the ability to make live calls in some situations.

A. Cost

SMS is widely used in Uganda for all types of communication. Women communicate with their husbands, men with business partners, and everyone with friends and family. It is generally a secondary communication medium, with direct calls being much more popular. There are sets of the populace who make no use of SMS at all, particularly older female users.

The primary reason people cited for using SMS was cost. Rural Ugandan users are very price sensitive, and an SMS message can be cheaper than a direct call for communicating a simple idea. Direct calls on the MTN network, which was most common in these villages, cost 5 Ugandan Shillings per second (about US$0.20/min). An MTN to MTN SMS cost 50 Shillings (about US$0.03), with cross-network SMS costing 130 Shillings (about US$0.08) [9]. The users indicated that a significant part of the time spent in phone calls was for introductions and greetings, which are not necessary with SMS. The price benefit of SMS was emphasized heavily in every village, every time, by nearly every user. This is not surprising, considering that the 2006 Human Development Report lists the per-capita GDP of Uganda at US$245 per year, or less than $1/day [10, page 333].

An offshoot of the price concern is the increased control and finer granularity of SMS costs. For instance, if you have 100 shillings and want to communicate with two people, it is hard to control your direct calls precisely to have enough time for both. However, with SMS it's easy to communicate with both acquaintances. Users said that they did this often, budgeting communication costs.

B. Accessibility

As users sometimes have to wait hours, hike miles, or climb trees to have voice conversations, there are serious access issues with direct calls in rural areas, especially if the receiver is also unlikely to be in coverage.

Nonetheless, the advantages of live calls are obvious. The largest advantage is the immediate feedback you receive when using a direct line. This was often cited by subjects as the primary reason for using direct calls instead of SMS. Examples mentioned by users include emergencies and time-sensitive information such as commodity crop prices.

Users also suggested literacy benefits. Voice calling is very simple technology with which everyone is familiar. Dialing a number is also easier than using SMS, more so for vision impaired users.

Users believed that hearing a particular person's voice made the conversation more serious for business purposes, and more meaningful for personal uses. This sort of information can not be transferred in a text-based system such as SMS.

SMS communication has serious accessibility concerns in Uganda, evidenced by the fact that users overwhelmingly expressed frustration with the technology. Literacy is common in Uganda, but still a problem and a limiting factor on the accessibility of SMS. Although the actual cost of an SMS at 50 Shillings (about US$0.03) for 160 or less characters is quite low, the input method is the biggest hurdle, as typing characters in a local dialect is difficult.

Also, users complained about not knowing when a message was delivered. This is curious, because every cellular network in Uganda supports message receipts. We informed the subjects about this, and instructed them in how to use it. The interface for this change is quite complicated, and likely the stumbling point. We do not know if this will change their behavior.

When pressed for advantages, a few users did cite privacy as a reason for preferring SMS. SMS allows for quiet communications in areas where there are always people around to hear you. This was not a common concern, however. We discuss privacy further in Section V-D.

C. Applicability

Throughout the study, it was very clear that connectivity is a huge problem. We chose our study locations based on connectivity concerns, so this is not a surprise, but it was striking how easy it was to locate villages with such connectivity problems. Any rural area in a valley or on the side of a hill without a tower was likely to have connection problems. This is because the cellular providers typically place the GSM base station on a hill that services the main trading area, and connections are unreliable without line-of-sight to that tower.

The area with the worst maximum loss characteristics among the intermittent villages was the first village in Mpigi, having up to three days of downtime each time the network failed. The last village we investigated had the worst average behavior (apart from the disconnected villages), experiencing loss multiple times every day. As one user claimed, "There is no consistent day". The majority of the ten villages had characteristics between these two extremes. In all cases, villagers were negatively affected by the lack of consistent network coverage.

The reasons for the network problems were not always clear. Users claimed that weather was a primary indicator of network loss, with it going down during storms or other heavy weather. Some villages experienced periodic failures in the morning and night, indicating congestion at those times. Lastly, there were (seemingly) random outages, with no external indications of the reasoning.

1) Users' Approaches to Intermittency: Users developed interesting mechanisms to deal with intermittency. The first mechanism was to search for a connection. If the closest tower dies, you may still be able to climb a tree and gain signal from another. This was the most common way to deal with a lost connection and urgent communication. Some villages were close enough to other coverage areas that walking was an option. All of the solutions require movement, which is a challenge for mobility impaired users.

For disconnected villages, the interesting questions revolve around how they deal with their lack of connectivity. As we were working in areas that were near coverage areas, users normally hiked to coverage, as the intermittent users did during outages. These users generally knew exactly where coverage began. For instance, in the disconnected village in Mpigi, the users pointed to an area around 300 meters down a main road. They claimed that location provides coverage on the MTN network.

2) Exploiting Asynchrony: The users did not use messages to deal with the lack of connectivity in their areas. This was simply because it did not work. We later found that their phones did not support polling for network coverage, so SMS messages can only be sent while the network is available. This is common, as most low-end phones do not support polling for network availability when sending an SMS. Only in the third village, with its typically shorter network failures, did users use SMS to avoid the intermittency. Presumably this is because the failures were often shorter than the timeout on sending SMS. We believe that this provides a good indicator that if the phones did support polling for connectivity, both text and voice messages would be used to deal with intermittency.

Messages were commonly used to deal with the *receiver's* intermittent connectivity. The users would send messages to receivers in highly intermittent areas, under the assumption that a direct call would fail. The key difference between this case and the previous one is that the network is storing the message. This indicates that if we implemented a store-and-forward network on the communication device (as we do in the trials), messages would be used to deal with intermittency on the sending side as well.

D. Comparison with mPhone

We asked users to compare the mPhone against alternative technologies, namely SMS and direct calls. The mPhone was greatly preferred over SMS. In fact, all users, given equal price, preferred to send a voice message over a SMS. As one user claimed, "There are no advantages to SMS". Users noticed that voice messaging was quicker than the time it takes to send an SMS, and nearly as speedy as direct calls, assuming they did not do any editing of the message before sending. Voice messages were found to be much easier to use, easier to understand, and easier to explain to illiterate relatives, who are a common group of people with whom to communicate.

With significant prodding, we gathered a few reasons a rural user may prefer to send an SMS over a voice message. The primary reason continued to be price. Users would send an SMS occasionally if the price was significantly lower than a voice message. Voice messages also do not provide the sound privacy of SMS, with one individual suggesting this as a reason to send SMS instead of a voice message.

Still, the mPhone has greater potential for privacy than direct communication. The privacy concerns revolve around the crowded nature of villages, where users have little personal privacy and thus sometimes prefer SMS. Although we did not explore this with users, voice messages should also help with privacy. The user controls the time for both creating and listening to messages, and thus can wait until they have sufficient privacy, at least in rural areas.

Users were not convinced that messages could replace direct calls. There were use cases, such as emergencies, where messages were not able to fulfill the users' needs. However, so long as the price of the voice message is lower than that for the direct calls, users would still benefit from the system. Voice messages have most of the benefits of a direct call, as determined by the users. As one user in Kiboga said, "It's a lot like direct calling, we're talking". During intermittent network connectivity, users preferred to send a mPhone message rather than hike or climb to connectivity. This demonstrates the utility of this form of communication in these rural regions.

Overall, the users loved the mPhone system. As users preferred mPhone over SMS for asynchronous communication, it would be a great drop-in replacement for SMS. The advantages from this form of asynchronous communication mean that

users would send more mPhone messages than they currently send SMS messages.

We also received positive results for using mPhone to deal with a lack of connectivity, with users wanting to send messages rather than hike for a call. However, even in that case, users wished to have the choice between these two options.

We asked the users about all of the pricing schemes available, and they predictably preferred the one with the lowest cost for whatever message they were sending. Assuming this is not an available option, they preferred per-second pricing. This is because the recording mechanism would allow them to very precisely budget their communications. The users commonly used the fine granularity inherent in SMS for this very reason, indicating that having an even higher granularity messaging system would be of great benefit.

VI. Related Work

There are a number of providers offering "Voice SMS" services. Some examples are Kirusa [11] and Bubble Motion [12]. These are implemented in certain provider's networks, including Vodafone, Airtel, Grameen Phone, Warid, and others. These provide basic voice message functions. The user dials a particular number, indicates the user to send to, and then records a message on the server. However, the user must be directly connected to the server for this to work. We believe it is important to store the messages on the handset rather than the server to provide utility while out of coverage. On the plus side, the phones have no new software, easing adoption. Overall, we believe that these systems provide some usability benefits, but do not address connectivity problems.

Core Mobility [13] provides an asynchronous voice messaging system with a software application for the phone. This system is deployed on the Sprint network in the United States. Their system downloads messages in the background, storing them locally. However, this system is also not optimized for the developing world. The network has not been optimized to discard the packets if there is congestion or loss. Also, the status of sent messages during network loss is unclear. We believe this technology is the closest to ours, in terms of applicability to the developing world.

All of these alternatives price on a per-message basis. The analogy to SMS implies a per-message pricing scheme, which we found to be suboptimal for users' needs in the region. The users prefer granularity in their pricing scheme, which allows them to budget their communications more effectively. In addition, we see no reason to force messages to be short, which implies a need for pricing based on bandwidth or time.

VII. Future Work

Given the positive user response to the model, we hope to work toward a much larger deployment in East Africa with one of the local GSM carriers. The provider's billing system must be modified, allowing for competitively priced asynchronous messaging.

As stated above, we have implemented a Symbian client using GPRS rather than WiFi. Though Symbian phones are not technically "low-end", they are sufficiently cheap to conduct the next phase of the project. The implementation is very simple, allowing it to be adopted to various low-end phones when we select a carrier to work with.

VIII. Conclusion

We believe that voice messages have an important role to play for rural users in emerging regions. They preserve the richness of voice, its fundamental ease of use and support for low literacy. At the same time, voice messages should be much lower cost than live calls and also work better in areas with intermittent or no coverage.

To understand the value of voice messages to these users, we developed a prototype cellphone system with voice-messaging capability. We deployed it in ten rural villages in Uganda and conducted focus group discussions with a total of 230 participants. The prototype allowed users to send and receive messages and allowed us to understand their reactions to both the messages and various potential pricing schemes. We explored how users in emerging regions currently deal with intermittent coverage and their views of the trade-offs between SMS and live calls.

We found that voice messages were very popular and uniformly preferred over SMS due to their ease of use and the richness of voice compared to text. We also found that voice messages would work well in areas with intermittent or no coverage and that users would often prefer sending a message when out of coverage over walking to an area with coverage to make a live call. Voice messages were not viewed as a replacement for live calls, but rather as a complementary model that could be cheaper and more widely accessible.

Based on these results, we aim to develop a more complete system that we can deploy with a cellular carrier in Uganda.

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