Developing a Campus Emergency Management Information System (CEMIS)

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Abstract: *Mobile phone technology is driving not only communication but also increasingly emergency and disaster management. Natural disasters and man-made threats such as terrorism constitute emergencies that are common today. Cellular communication provides a tremendous potential to increase efficiency and effectiveness in this area by propagating information efficiently to all the right parties in the right places. There are opportunities for the use of mobile phone technology in early warning, preparedness and other mitigation activities that can help organizations in Kenya to build resilience in the face of the ever growing threat of such disasters. This study therefore explores, from an institutional context, how students in campus use mobile phones in emergency management, the factors underlying their extensive use, the challenges that are faced and how this use of mobile phones related to social organizations and interactions. Ultimately, an emergency management information system (CEMIS) is developed that utilizes the power of text messaging to build resilience in the face of ever growing threat of emergencies and disasters. The study recommends more proactive developments in text based applications to mitigate the adverse effects of disasters in institutions of learning.*

Keywords: *Cellular Networks open BTS, SMS in Emergencies, SDR,*

I. Introduction

The explosive nature of adoption for cellular communication in Kenya and in Africa as a whole has brought about many benefits. Cell phones are small dynamic low power consuming devices with a very simple and intuitive user interface that is very flexible which makes them highly suitable for populations where energy and other infrastructural shortages, as well as sparse population densities, language and computer illiteracy, are common. Cellular communication has the potential to revolutionize developing regions. The technology can be utilized in delivering both global Internet content [1] and region specific information [2] to remote communities. The range of cellular applications spans from micro-finance transaction management [3] to education [4] and health care [5]. Accessibility to information is crucial for economic growth of a region [6] as well as for political freedom [7]. While the above benefits can be observed worldwide, the way communication tools are used often varies among different communities, age groups, religious groups, sex etc. Local ethnographies steer the appropriation of technology according to indigenous customs [8, 9].

Mobile phone technology is driving not only communication but also increasingly emergency and disaster management [10]. Natural disasters and man-made threats constitute emergencies that occur unexpectedly that require careful management. Cellular communication provides a tremendous potential to increase efficiency and effectiveness in this area by propagating information efficiently to all the right parties in the right places [11]. From an organizational context, mobile phones are mainly being used in emergency and disaster response. There has been a steady integration of mobile phones in emergency and disaster management, through mobile-phone based applications [12]. There are opportunities for the use of mobile phone technology in early warning, preparedness and other mitigation activities that can help organizations in Kenya to build resilience in the face of the ever growing threat of emergencies and disasters. The threats of terrorism are real in Kenyan organizations such as in institutions of higher learning.

Among the drivers of the uptake of mobile phones in emergency and disaster management has been their near ubiquitous nature – mobile phone penetration rate in Kenya. Falling handset costs and increased mobile phone functionality has further strengthened the technology's appeal with the convenience and security offered by mobile phone-based cash transfers for example, boosting the technology's use in emergency and disaster response.

The spin-off benefits of using mobile phone technologies include social capital aspects such as feelings of empowerment due to the ability to communicate and access much needed help [13]. Among the challenges identified in the use of mobile phones in emergency and disaster management in Kenya include the high start-up costs due to technology and training needs, poor mobile network connectivity in remote areas, illiteracy, reluctance to embrace the mediation of the technology in aid delivery and the misuse of mobile phones. One of the most consistent overriding messages to emerge from the research is the potential benefit of the timely spread of information in response to a disaster. While mobiles are only one element of a whole array of means of communication, the technology is especially effective at decentralising information and diffusing it rapidly to where it is most urgently needed [13]. After looking at several recent case studies, including the Indian Ocean tsunami, Hurricane Katrina, floods in central Europe and the Bam earthquake, the conclusions identify the role of mobile at each stage of a disaster, from early warnings to long-term recovery, indicating where mobiles make their most valuable contribution, and how this might be enhanced in future. This study therefore explores, from an organizational context, how and why the selected organizations in Kenya use mobile phones in emergency and disaster management, the factors underlying their extensive use, the challenges that are faced and how this use of mobile phones related to social organizations and interactions. Ultimately, an emergency management information system is developed that utilizes the power of text messaging to build resilience in the face of the ever growing threat of emergencies and disasters.

The study recommends research into more proactive uses of mobile phones in disaster management in Kenya as the technology is predominantly being used in enhancing emergency and disaster response. There are opportunities for the use of mobile phone technology in early warning, preparedness and other mitigation activities that can help Kenya to build resilience in the face of the ever growing threat of emergencies and disasters.

II. BACKGROUND

The following is a research study on cellular communication among students in institutions of higher learning in Kenya. The study is primarily designed to explore the feasibility of using cellular communication to manage emergencies and mitigate effects of disasters in colleges and institutions of higher learning. It is based on a survey, primary research study, undertaken in a university campus in Kenya to investigate the relationship between mobile communication and emergency management in times of disaster among students. The scope of study addresses the following main issues

- To study the attitudes and relationship of students towards cellular phones
- To enumerate the usage pattern scenarios to draw peculiarities
- Examine the way students relate to the functionality of mobile phones as well as assess observable phenomena
- identify the different associations with cellular phones
- understand students perception on emergency security and disaster handling of cellular communication devices
- outline the feasibility of developing an SMS based system for disaster mitigation named CEMIS

III. METHODOLOGY

The entire primary research study was conducted in Eldoret University campus utilizing quantitative research method. In order to provide a snapshot of cellular phone usage scenarios amongst students, data collection was done through a detailed opinion-questionnaire administered across admission levels, faculty, departments and gender. In addition to the questionnaire, 30 participants completed a diary to record in great detail six days of their phone usage. The diaries were supported by the actual phone logs. Respondents were selected to maximize the diversity of the insights, proportionally reflect student's population across gender and background locality. No financial incentives were involves in the cause of applying multiple approaches that allowed us to develop a nuanced and detailed picture of the mobile phone usage scenarios. The technique used for data collection was one-to-one interviews. The individual responses obtained was compiled, processed and analysed to arrive at the conclusions on various issues. The instruments for data collection were designed to elicit information on demographic and psychographic aspects of the respondents. The psychographic variables included attitudes towards usage of cellular phones, social issues and behavioural patterns. The questionnaire had a mix of open-ended and close-ended questions in it. The open-ended questions gave an added qualitative experience to the instrument, provided the logic or rationale for the behavioural patterns and helped generate insights.

CEMIS is a prototype implemented in a laboratory setting using cheap imported hardware and locally available components. OpenBTS Development Kit is imported from Range Networks[14, 15] and comes pre-configured with Universal Software Radio Peripheral 1 (USRP1) a product of Ettus Research that supports OpenBTS software, two Vert900 multiband rubber duck antennas, RFX 1800 daughterboards with 1.5 GHz Transceiver of100+mW output, 64Mhz clock and ZTE test phones. Two HP Laptop computers of 1.8GHz speed and one GB RAM running Ubuntu 10.0 linux and asterisk programming radio communication was utilized in CEMIS construction. Although the system carries both voice and text messages, the system was evaluated on an SMS-based platform most popular with student fraternity.

General Usage of Mobile Phones Study Findings

Key Findings

1. Text messaging is the most widely-used cellular communication feature but voice calling remains popular among campus student phone owners and email continues to retain a place of prominence in the smartphone era
2. Social networking, video consumption, and music/podcasts are especially popular with students in campus environments

Key Themes of the survey study

- An "experience sampling method" of mobile phone owners over the course of a week illustrates how young adults have deeply embedded mobile devices into the daily activities of their lives.
- The experience sampling survey illustrates that cellular phone usage often produces feelings of security, productivity, happiness, and users also feel a sense of belonging and association in a social community.
- Cell phones are widely used for navigating numerous important life activities, from researching a health condition to accessing educational resources.
- Lower-income and "mobile phone-dependent" users are especially likely to turn to their phones for navigating job and employment resources.
- A majority of Smartphone owners use their phone to follow along with breaking news, and to share and be informed about happenings in their local environments or communities.

Most research participants interviewed had only one mobile handset. Of the 7% that had more than one mobile handset, most had multiple phones to reduce on the inter-network calling costs. The reason for owning multiple phones rather than simply multiple SIM cards is likely due to a combination of factors including the hassle to switch SIM cards in and out of one phone, and also in order not to miss any calls on either line. More common than multiple handsets are multiple SIM cards. 60.5% of the Kenyan youth own a mobile phone, but 82% of the Kenyan students have at least one active SIM card (safaricom, 2012); 15.2% of them had 2 active SIM cards (safaricom, 2012). These findings indicate that approximately a fifth of the Kenyan young population own a SIM card even if they do not own a mobile phone. Therefore, even if they do not own a mobile handset, they likely have at least a SIM card. This allows these users to have their own phone number and credit to make a call on any borrowed mobile phone device. If a mobile device is owned, owning multiple SIM cards entails swapping of SIM cards depending on which Mobile Network Operator (MNO) service is favourable at that particular moment. Another reason for a greater number of SIM cards than handsets is because of the popularity of dual SIM phones-one handset, which can hold 2 or even 3 SIM cards at a time (such as the Dual SIM Nokia X1-01 and Nokia C2-00).

Out of 45 respondents interviewed, each had either a basic, feature or smart phone. Female participants possessed most modern phones while majority of male participants contended with basic featured phones

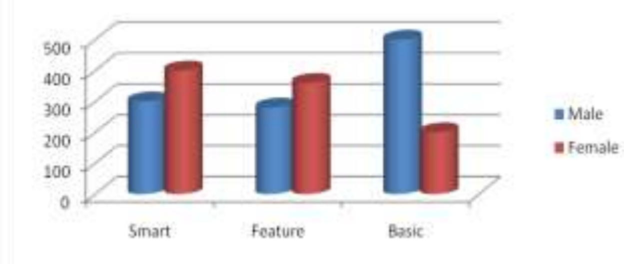


Figure 1: Phone Type Category by Gender

Overall, Safaricom holds 64% of the Kenyan Mobile Phone Subscription Market (CCK 2012). Airtel holds 16.5%, Orange 10.5%, and Essar Yu 9.0% as depicted in figure 2 below. In the study's survey research participants, 55% use a Safaricom line. Airtel followed closely at 33%, Orange at 13%, and Yu at 4% - this is shown in figure 3. The huge number of Safaricom and airtel subscribers could be attributed to a number of factors including the fact that the operators have been in existence over a long period of time and also offer mobile-money transactions.

Figure 2: Mobile Phone Subscription Market

Figure 3: Mobile Phone Dominance Usage

Time for Making Calls

The majority of the calls were made in the morning hours over a six-day diary period, and then again at night. This may be due to the fact that these respondents are engaged in academic activities during the day and therefore hardly get time to make as many calls in middle of the day. Further analysis of the diary data shows that more calls were made during weekends compared to weekdays (Day five and six represents Saturdays and Sundays). Despite most calls being made in the morning, the longest average duration of calls was observed in the night hours- 6 minutes on average as compared to daytime when the average was about 4 minutes.

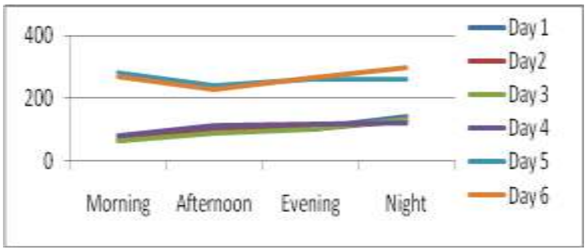


Figure 4: Call Counts over a Six day Period of the Diary study

Most SMS messages were sent in the morning as well as in the afternoon hours. This trend is similar to calling service and could again be attributed to the fact that the respondents are less preoccupied at night. Overally, a declining trend was observed as the days progressed from morning to night and call contacts overtook text messaging.

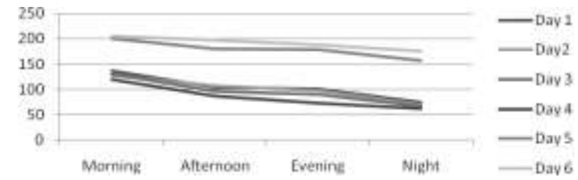


Figure 5: SMS Counts over a Six Day Period of the Diary Study

Among cell phone owners in campus, the most popular activity is sending text messages. Overall, a median of 80% of mobile phone owners across year-of-admission and gender surveyed say they do this with their phones. This includes 95% in ladies and 92% in gentlemen. In all, at least half of cell phone owners say they send text messages with their devices. The second most popular activity is making calls or receiving calls. A median of 53% among cell phone owners say they have done this in the past one week. Using mobile devices for making calls and receiving calls is most popular with ladies (60% among cell owners) and men (57%). The survey found out that some 70% of all cell phone owners and 86% of Smartphone owners have used their phones in the previous 30 days to perform at least one or several of the following activities:

- 59% have used their phone to get help in an emergency situation
- 60% have used their phone to get up-to-date information on academic timetable, activities and events in campus
- 41% of cell phone owners have used their phones to coordinate a meeting or get-together
- 35% have used their phones to solve an unexpected problem that they or someone else had encountered
- 30% have used their phone to decide whether to visit a friend, relative or a restaurant
- 27% have used their phone to get information to help settle an argument they were having
- 23% have used their phone to look up a score of an examination, sporting event or to follow along with breaking news, share and be informed about happenings in their local community
- 67% use their phone to share pictures, videos, or commentary about events happening in their community, with 35% doing so frequently.

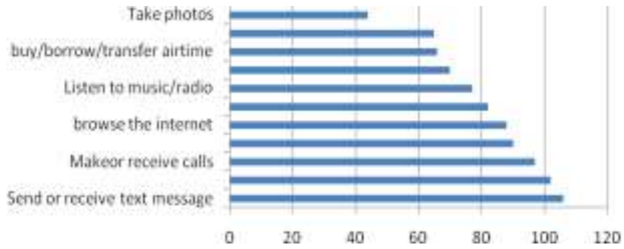


Figure 6: Popular Activities Among Cell-Phone Owners in Campus

IV. CEMIS SYSTEM DESIGN

CEMIS is a low-cost cellular system that leverages existing, unmodified mobile phones and SIM cards to provide voice and text messaging for free within a network [14]. The system envisions an underlying infrastructure for low bandwidth applications that make use of short text messages and therefore enhances with functionality that enables such applications. In the following section a dscription is made o f a text messaging operation of C E M I S , present the integration of C E M I 's core components, and discuss the extensions implemented to facilitate SMS applications [14].

Figure 7: CEMIS architecture.

1. Architecture

As depicted in Figure 1, CEMIS utilizes free open-source software to provide voice and text message services. The base stations run OpenBTS, which implements the GSM stack and communicates with the associated cellphones using the standard Um radio interface for 2G and 3G cellphones devices. OpenBTS is also responsible for translating GSM messages to SIP, which allows the use of low cost generic IP backbone infrastructure as opposed to an expensive commercial-grade GSM backbone. The SIP translation enables the use of free

VoIP server software to serve as a Mobile Switching Center for routing calls. To route calls within and outside the system, FreeSwitch connects to OpenBTS via SIP and RTP and routes calls both in intra and inter BTS local scenarios. This makes it easier to route calls outside of the network to commercial cellular, fixed line and VoIP networks using SIP and SS7[15]. Through customising python scripts, FreeSwitch allow extension of the basic routing functionality to facilitate cellphone based applications.

CEMIS utilizes Sipauthserve and SMQueue to handle user authentication and text messaging. SMQueue is the SIP-based equivalent of an SMSC (Short Text Messaging Central) in a commercial-grade system which interfaces with OpenBTS and makes use of commodity IP networks to transmit SMS (Short Message System). It can interface with commercial SMSCs using SS7 and SMPP. The SMQueue implements a store and forward SMS queue functionality that allows messages to be delivered in a delay tolerant fashion. This is of great importance for areas with intermittent cellphone access and electric power availability as users are often either out of range or have their cellphone powered off. User authentication and mobility is by the system leveraging Sipauthserve - a database server with an interface to process SIP REGISTER messages to track mobility. SMQueue and Sipauthserve are queried by other network elements (e.g. FreeSwitch and OpenBTS) through SQL.

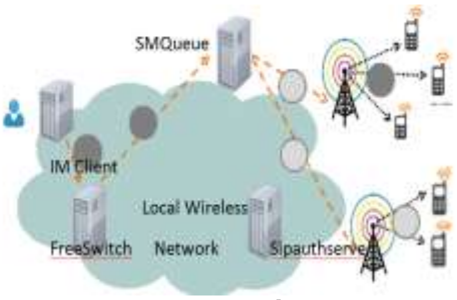


Figure 8: IM-SMS system architecture.

2. Support for SMS-based applications

Cell phone communication is an increasingly popular method for students to stay connected and is widely used for applications other than plain voice and text messaging. Low data rate applications have been utilized in security [15], education [16], web browsing [17], agriculture [18, 19, 20] and health care [21, 22, 23, 24, 25]. The interest in the design of CEMIS is in enabling functionality that will support such applications. Beyond simple SMS, we need functionality that supports SMS broadcast and multicast, and in particular does so through an Instant Message (IM) interface. IM-SMS interface enables fast typing and rapid outreach to a large set of subscribers. The interface has a wide variety of uses. for instance, a student leader could use it to notify subscribers of a change in an event schedule, or of an alarm notification of an emergency scare. Such a solution exposes an API that allows development of applications that can leverage the text broadcasting functionality to automate message generation, obviating the need of an actual person to send IM messages facilitating a variety of automated services, such as automatic alerts, dissemination of crucial information and updates. The design unifies this IM extension with SMS to enable rapid distribution of instant messages from any packet data network. The unified mode of messaging is asynchronous by design to minimize resource wastage and guarantees only best effort delivery. IM client is implemented using the open-source multimedia communication library PJSIP which implements the SIP protocol stack and supports all three NAT traversal functionalities, i.e. STUN, TURN and ICE which facilitates routing of SIP traffic from various networks, including private IP networks such as student hostels, lecture halls and local networks while also exposes all functionality in suitable APIs for a wide variety of systems, including desktop and smart phones, and meets the key design goals identified above.

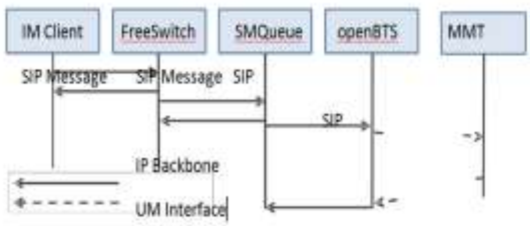


Figure 9: Message exchange between system entities to send a SMS (a) from the IM client to a CEMIS subscriber and (b) from a CEMIS subscriber to the IM client.

Figure 9 presents a typical usage scenario of our IM client. The client needs to be installed on a machine that can access the CEMIS core network. The IM client then communicates directly with FreeSwitch when sending text messages to users associated with CEMIS. FreeSwitch handles the delivery of a text message to the end user.

Any new user of the IM service is manually provisioned with a valid SIP address of record in the Subscriber Registry (Sipauthserve on Figure 8). An IM user is identified by their SIP address of record (SIP user identity) and unique phone number. SIP identity is used by internal subsystems, i.e. FreeSwitch, SMQueue and OpenBTS, to validate and route any SIP traffic related to a particular IM user. IM client's phone number is exposed to the other cellphone users of CEMIS, so that the sender of a message can be identified and the recipient can respond if needed. To reach the IM client, CEMIS also stores the IP address of the host where the IM client is installed which necessitates an IM user to utilize the IM service only from a pre-provisioned host address. This mechanism, however, can later be extended to a dynamic address binding scheme. Upon sending a message to a CEMIS user

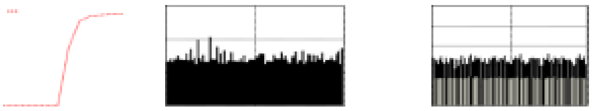
(Mobile Message Terminator – MMT), the IM client generates a standard SIP MESSAGE request [26], that contains the message in plain text format as well as the SIP address of record of the recipient. This SIP MESSAGE is then sent to FreeSwitch, which forwards it to SMQueue after validating the identity of the sender. SMQueue stores the message in its store-and-forward queue and attempts best effort delivery to CEMIS base station where the recipient is registered. Because the entire SMS functionality in the system is asynchronous, a real time session is not required for transmission of the IM message to its recipient. This design makes messaging particularly suitable for remote environments, where a user is not likely to be associated with the network at the time the message is sent. If the user is not associated, SMQueue stores the message and regularly attempts delivery. This design avoids waste of resources typically associated with synchronous/session based messaging.

3. Controlled experiments

This experiments focus on text messaging and instant messaging to SMS of the system. During evaluation, Open BTS' capabilities as well as limitations of the GSM modems is taken into consideration to ensure the accuracy of performance measurements. Open BTS can handle at most 84 SMS messages per minute and 7 simultaneous calls; therefore traffic is not generated at a higher rate so that delay can accurately be measured. GSM modems incur a delay of about 0.5 seconds to execute the commands associated with sending a single message. Finally, there needs to be an inter-message delay of 6 seconds to ensure the GSM modem does not become overloaded with outgoing messages. When overloaded, the modem fails to send messages to CEMIS.

The lab setup includes one Range Networks unit that operates as a self contained system running all four services – Open BTS, Free Switch, Sipauthserve and SMQueue. This test setup utilizes the readily available network infrastructure in the campus to connect the base stations. We therefore use an existing wired connection for the backbone link between the indoor installation and CEMIS. The modems are connected to a server that can be accessed from the Internet and then automate SMS between the two modems. End-to-end delay for delivery of a single message is evaluated and assesses the delay components incurred by each element of CEMIS. Figure 8 gives an overview of the SIP message exchange associated with delivery of a single SMS from a Mobile Message Originator (MMO) to a Mobile Message Terminator (MMT). In our evaluation of SMS delivery we focus on two scenarios. First, we evaluate delay for delivery of messages to users associated with the network. We then evaluate the impact of SMQueue load on the end-to-end delay by increasing the number of transmitted messages to users that are provisioned but not associated with the network. The latter increases the load of pending messages in SMQueue. We then measure the time it takes for a message to be received by a registered user.

To evaluate the delay for message delivery to a user associated with CEMIS, 50 consecutive messages are sent, with 10 seconds inter-message delay. 45 of these messages were received by CEMIS; five messages failed to depart from the sending GSM modem. Figure 10 presents our results. In Figure 9(a) we plot a CDF of the end to end delay. As the graph shows, 80% of the messages were delivered to their destination in 6−9 seconds; the maximum observed delay is 15 seconds. The average delay over all 50 messages is 9.06 seconds with standard deviation of only 1.2 seconds.



(a) Delay(s) (b) SMS ID (c) SMS ID

Figure 10: Testing of 50 SMS transmissions to associated users. (a) CDF of end to end delay; (b) break-down of delay components per message; and (c) zoom of non-Um delay components.

V. CONCLUSION

SDR and software that converts GSM signals to voice over IP allows design of low-cost local cellular networks, which can notably improve communication and therefore mitigate the adverse effects of disasters and emergencies caused by terrorism activities. This paper therefore contributes to the research domain in several ways; the study explored, from an institutional context, how students in campus use mobile phones in emergency management, the factors underlying their extensive use, the challenges that are faced and how mobile phones related to social organizations and interactions. Eventual design of a low-cost cellular network named CEMIS that utilizes the power of text messaging to build resilience in the face of ever growing threat of terrorists and other disasters. The study recommends more proactive developments in text based applications to mitigate the adverse effects causes by disasters in institutions of learning.

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