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International Journal of Computing and ICT Research

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The African Development Dilemma: Quality or Mass Education

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1. INTRODUCTION

Uganda is to vote for the next President on February 18, 2011. According to Dr Frederick Golooba-Mutebi of Makerere University Institute of Social Research, the new government will inherit a lot of serious problems including "an education system crippled by large number of pupils/students with few and poorly paid teachers," [Mugerwa, 2011]. From the time all African nations got independent, the overriding desire of every independent country has been to provide and expand the education system to as many as the financial resources of the country can go. This drive is based on long held views of many Africans that education contributes handsomely to combating ignorance, disease and poverty. It is also based on the fundamental principle that every African kid has the right to basic education and that it is the duty of government to provide it to the limits of available resources.

Every government understood, at the time of independence, that the attainment of this is through the provision of the Universal Primary Education (UPE) to all the nation's children. Driven by this desire, African governments at different times after independence set themselves to do just that, although few had the resources to support the move. Besides the political motives and the natural desire to bring about national development, there were external forces in the play. In 2000, the United Nations, in an effort to spar rapid international development through international cooperation, enacted the United Millennium Declaration which included eight measurable outcomes as goals. These become the United National Millennium Development Goals (MDGs). The Goals represented human needs and basic rights that every individual around the world should be able to enjoy. Rights like freedom from extreme poverty and hunger; quality education, productive and decent employment, good health and shelter; the right of women to give birth without risking their lives; environmental sustainability and women and men live in equality. In particular, Goal 2 in the MDGs, was to ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling. However, in 2010, when the United Nations met again to take stock of the progress made after 10 years, there was a mixed picture as follows (Ki-Moon , 2010]:

- Hope was dimming for universal education by 2015, even as many poor countries made tremendous strides
- Sub-Saharan Africa and Southern Asia were still home to the vast majority of children out of school

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- Inequalities within and between nations were presenting the greatest threat towards progress towards universal education

One of the reasons for this mixed picture, especially in Africa, was the growing debate about the value of mass education driven by the MDG policies many of African governments had embarked on and the quality of education resulting from UPE. Across East Africa, for example, where Kenya (twice), Uganda and Tanzania have already embarked on UPE, there are growing problems. At the time of the abolition of school fees no or limited measures were put in place to replace the lost revenue for schools and districts. Schools and districts were at a loss as to what they could do about this lost revenue and how to meet the expenses of added mandates of UPE. With unexpectedly enlarged enrolment and limited money from the ministries of education, schools and districts started charging revenue as building fees. These varied from school to school and district to district. However, very quickly there were raised parental concerns and outcry to governments and governments came in to abolish these channels of school and district revenue. Yet the resources from government to schools and districts to meet the new UPE mandates were very limited and constrained.

The result of curtailed local revenue collection, limited government resources, overwhelming class overcrowding, no new teachers, and the severe and strained supply of teaching and learning materials together created near unsustainable education environments and heated political debates across Africa about the value of UPE. To try and remedy the situation, governments started knee jack reactions that included a requirement of non-retaining of poorly performing students and the recruitment of more unqualified teachers. These government interventions had immediate serious consequences including increased pupil teacher ratios, high drop outs, unexpected increase in education expenses to parents and a drop in the quality of education. As professor Daniel N. Sifuna observes [Sifuna, 2005], while free primary education has increased participation, it has at the same time created considerable problems. It has exacerbated the problem of teaching and learning facilities. As a result of the high influx of new pupils, classrooms are congested. Many of the preliminary surveys seem to show that the existing facilities make a mockery of the free education program. This has upped a level in the debate UPE vs quality of education.

With five years to go until the end of the MDGs, limited national resources and the reluctance of the donor community not willing to commit more finances due to economic restraints back home, this debate is likely to continue.

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Implementing Is In Developing Country He Context: Towards Creating A Favourable Implementation Context

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Abastract:
The implementation of Information Systems (IS) in the higher education learning institutions in Kenya has been increasing and seen varied results. Research has reported higher chances of IS failures in developing countries. The organizational implementation of IS has continued to be a focus for IS researchers, and the organizational change perspective has been used to explore the actions and events that happen in organizations towards implementation efforts. A case study based on empirical investigation of the implementation process of a student management system in a university context, in Kenya, is used to explore the efforts of the implementers in creating an enabling environment for a successful implementation process. The study is guided by the authors' modification of Gallivan's framework [Gallivan 2001] and specifically focuses on the managerial construct to illustrate the relationship between organizational context and the student management system implementation process. The paper illustrates that organizational context shapes managerial interventions and decisions; that this context is both enabling and constraining in the creation of a favourable implementation context by implementers; and that IS implementation process results in organizational change that requires continuous change management mechanisms.

Keywords: Organizational IS implementation, Managerial Change Interventions, Higher Education Institutions (HEIs)

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1. INTRODUCTION

With the rapid evolution of information and communication technology (ICT) applications, Cadle and Yeates [2004] observe that the implementation of IS in organizations has become a complex process often involving several dimensions that include technological and organizational processes. Therefore, the introduction of IS within organizations almost invariably results in a wide variety of consequences that span from technological to organizational, that need to be explicitly reviewed and proactively managed. However, as Orlikowski and Hofman [1997] noted, effectively implementing organizational changes associated with the implementation of IS remains difficult. Nonetheless, world-wide, organizations are still involved in acquiring and developing IS to cope with the demanding environments that they operate in.

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One such category of organizations is universities, often referred to as Higher Education Institutions (HEIs) in the literature.

Globally, there are tremendous changes in the higher education sector, resulting in increased pressure to operate as commercial entities as a result of diminishing government funding, escalating costs, increasing student numbers, growing demand for accountability and quality, and increasing competition [Seng and Churilov 2003]. Students are also joining universities with more demanding expectations, in terms of information and communication technologies and administrative efficiency. As a result of this, HEIs are moving away from traditional ways of managing towards new managerial styles. The emerging managerial styles are characterized by high staff student ratios; introduction of stringent financial planning and spending; increased focus on efficiency and effectiveness of individuals' and departments' research and teaching standards; and above all introduction of information support systems to gain a competitive edge [Seng and Churilov 2003].

From the foregoing, the role of IS in the 21st century is undisputable in the HEI sector. In a university environment, typical information systems include timetabling systems, library management systems, finance systems, student records systems, payroll and personnel systems, and facilities management systems. These systems are geared towards providing a university with effective, efficient administrative and academic processes, thereby enabling and facilitating sound management and control of the university.

Universities as organizations encounter similar challenges to commercial enterprises such as human and material resources planning constraints. Further, universities have also been noted to have distinctive features such as unique culture of the academy, institutional status, multiple power and authority structures, professional and administrative values [Kezar 2001], thereby giving a unique context.

As Pollock [2002] notes, though worldwide changes to higher education as a result of new ICTs are increasingly researched and reported, we still understand very little of the particular dynamics associated with the implementation and use of mundane information systems. While it is agreeable that the implementation of IS involves significant change management problems and that the use and adoption of these systems have both organizational and individual implications at present, there is little research evidence about how to effectively implement information systems in non-commercial settings such as universities, and in particular universities in the developing countries.

Universities in Kenya are undergoing tremendous changes occasioned by diminishing funding from the government, external pressure from government ministries, stiff competition from external HEIs, and the ever-increasing demand for higher education. In tandem with the "new" styles of managing universities, the management of these institutions are adopting integrated IS to improve service provision and management of the universities.

The implementation of information systems is critical to universities due to the following reasons:

a) The investments in IS infrastructure and tools in universities is high and, given the budgetary constraints of these institutions, IS projects should be managed effectively to realize gains;
b) The reliance on information systems in universities is growing. This is especially so, as universities aim to provide world-class education standards and services, that is a step towards "modernization"; and
c) Prior studies have concentrated on IS implementation in commercial organizations, and therefore it is not entirely clear from these studies what factors are more critical to the success of information systems implementation in academic environments especially in a developing country like Kenya.

Indeed, the challenge of organizational implementation of ICTs and its related services as observed by Walsham and Sahay [2006] is in tackling and resolving the difficulties during implementation. Therefore effectively implementing IS in organizations becomes both a proactive and reactive process in response to information systems implementation intermediate challenges, thereby focusing on the implementers and their actions towards managing the process.

In this paper, we use data collected from a wider case study to address how a case university implemented IS *to illustrate how the university context influenced managerial actions that were initiated in the case institution with the view of improving the implementation of information systems in the higher education sector*.

2. THEORETICAL FRAMEWORK

2.1 The Importance of Context in IS Implementation

Information systems implementation and organizational change are related because implementation of information systems brings about organizational change, whether intended or unintended. The importance of organizational context in information systems implementation is thus important and has been recognized by many IS researchers. For example, information systems and organizational change have been considered as socially embedded action, studied through social constructionist and situated research perspectives [Orlikowski 1996; Ciborra and Associates 2000]. Rather than being neutral tools with generally useful functionality, information systems and their associated technologies and techniques are understood to inscribe social preferences that have been shaped historically in the environment in which they have been developed [Akrich, 1992], and we add, *and implemented*.

Research that takes a related view of information systems is that of social systems perspective. This perspective acknowledges the formal (rules and procedures) and informal (politics, norms and culture) subsystems of the organization coupled with wider environmental factors [Walsham 2001; Heeks 2000]. Research adopting the wider social systems view in IS has used Gidden's theory of structuration [Giddens 1984], particularly the concept of the duality of structure that refers to the recursive and dynamic interactions of social structures and technology. Research has illustrated the technology's potential to change the social and organizational structures and simultaneously be affected by these social and organizational structures in its design, implementation, and use [Walsham and Waema 1994; Rodrigues and Waema 1992].

Although the research we cite above acknowledges the importance of organizational context in general, we hereby argue that it applies to implementation context of IS in developing country higher education institutions, which is the subject of this paper.

2.2 Theoretical Framework

Drawing on the innovation implementation framework [Gallivan 2001] and the IT-change management model [Orlikowski and Hofman 1997], we conceptualize the organizational implementation process as consisting of a secondary adoption process, an organizational assimilation process and a continuous organizational learning process requiring continuous change management interventions. By reviewing [Gallivan 2001], and [Orlikowski and Hofman 1997] frameworks, the authors enhanced [Gallivan 2001] implementation framework by incorporating organizational learning, change management interventions and feedback loop to the implementation context (see Figure 1). Although in Gallivan's framework the secondary adoption construct is used to refer to the individual level, the advantage of the framework is its applicability to multiple levels of analysis. Hence, our notion of the secondary adoption is at the adopting unit level rather than at the individual level, thereby focusing on initiation and adoption decisions and actions at the unit level. The organizational assimilation is then conceptualised as the cumulative organizational adaptation and acceptance of the IS, with continued use and reliance resulting to routinization and infusion of the information system. The fact that we acknowledge and are informed by extant literature on the role of organizational learning to the implementation process, we enhance the view of organizational implementation by adding organizational learning to the implementation signifying the role of reflective actions by actors involved in the implementation process [Wausi 2009].

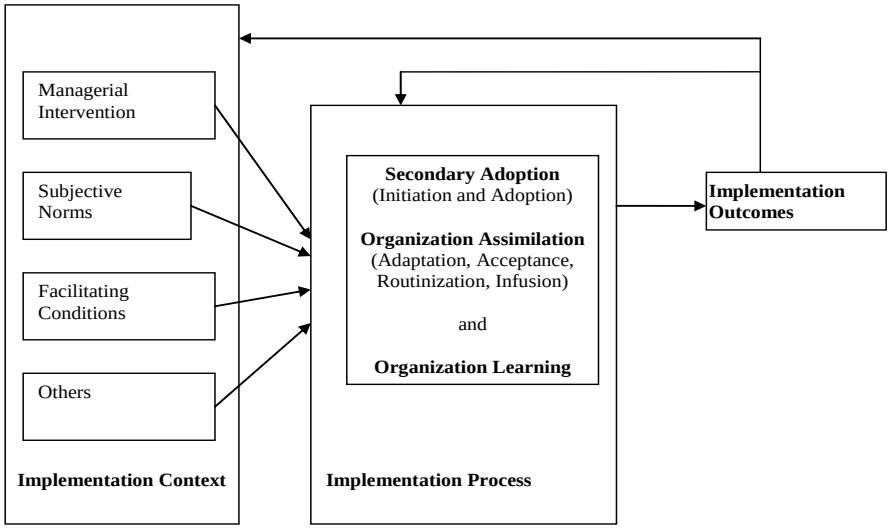

Figure 1 : Theoretical Framework: Implementation Context, Process and Outcomes [Wausi 2009]

The organizational implementation process happens in an organizational context and the context influences the process. The notion of implementation contexts for IS concerns an identification of various systems and structures in an organization that influence the implementation process [Walsham 1993]. Research, for example [Heeks 2002;Avgerou 2001; Walsham and Waema 1994;Walsham 1993] has shown that context influences the shaping of technology use in an organization. The context influences the implementation process by enabling and/or constraining the implementation process. The context is not constant and is influenced by the implementation process. Therefore the context illustrates systems such as power, cultural, economic, human resources and management structures within which the implementation process occurs which form an important basis for an interpretation of the process. The concept of context is thus wide, and in operationalizing the implementation context, we focus on actions and interpretations of events by people involved in facilitating the process. Further, not only do aspects of the context viewed as constraining or enabling the process need to be identified but also are illustrations of their influences deemed necessary in understanding the implementation process. The Table 1 defines the theoretical constructs that concern managerial interventions only in the framework. The complete definitions for all the frameworks can be found in [Wausi, 2009].

We focus on managerial interventions in this paper and only examine managerial and change interventions used in the case university towards efforts to effective implementation.

Construct	**Explanation**	**Operational Definitions**
Managerial interventions	a) Managerial actions that are geared to creating an enabling environment	Actions and events that • Indicate the provision, acquisition, allocation and enhancements of human and computing resources. These involve financial resources implicitly; • Indicate actions towards mandating, motivating or negotiating use of computerized application systems; and • Infer to monitoring and evaluation of process.
	b) Change management strategies and actions taken to counter resistance and enhance the adoption and	Strategies and actions taken by implementers and the organization • To enhance anticipated changes in response to the implementation process;

Construct	Explanation	Operational Definitions
	assimilation of computerized application system at unit and organizational level	• To respond to user experiences from use of the computer application system; and • To respond to opportunities provided by the implementation process.

Table 1: Theory Constructs definitions [Wausi 2009]

3. METHODOLOGY

3.1 Research Approach

To understand the organizational implementation of IS as innovations in the HEIs, we adopted an interpretive qualitative approach. The interpretive perspective, having its root in social science, is based on the ontological assumption that reality and our knowledge thereof are social constructions incapable of being studied independent of the social actors that construct and make sense of this reality [Khazanchi and Munkvold 2000] Individuals' perceptions about the world are influenced by experiences they have had. Thus, the interpretive approach tries to understand the phenomenon under study in a holistic way by offering explanations for observations made.

The research strategy used was qualitative and involved the use of qualitative data, such as interviews and project documents. A social setting is not controllable and continuously changes and we had no prior declared hypothesis to test and measure. Therefore we found the case study approach suitable for our topic.

A case study consists of a detailed investigation, often with data collection over a specified time period, of phenomena under study within their context [Hartley 2004]. Case study research has been used to study varied IS phenomena, particularly in system development and implementation [Pollock 2003; Rodrigues and Govinda 2003; Walsham and Waema 1994].

3.2 Identification of Organizations and Gaining Access

Our case study approach required a selection of sites within the higher education sector because our problem was investigating information system implementation phenomena in HEIs. The selection of the IS innovation in the organizations had to be done carefully to bring out a detailed understanding of the IS implementation in a typical HEI context. This therefore required that the IS application in the HEI had to meet the following criteria: be on *roll-out phase*, *had just been rolled-out* and *involved as many units as possible* within the organization. This criterion enabled us to reconstruct the history of the case, thereby circumventing the risks of "memory loss" of critical events by the participants.

Once the institutions that met our criteria had been identified, we negotiated access to these institutions. Factors crucial in gaining access to any organization for research purposes are the availability of informal contacts, the sensitivity or confidentiality of the phenomena under study and the perceived gain or loss that the "gatekeeper" approached for access has on the results of the study. A further issue is the relative power the individual approached to grant access has within the organization.

Our interest being on the implementation process, we sought to interview project team members of the implementation team, heads of departments, users of the IS selected to be cases, and the management staff of the institutions.

The adopted theoretical framework formed the basis for the development of data collection interview guides, qualitative questionnaires and document summary form, which were applied to data collection methods of interviews and document analysis. The interview guide and qualitative questionnaires were used concurrently. All qualitative questionnaires, based on the interview guide for the various categories of interviewees were emailed to participants prior to the interviews. The questionnaires enabled the participants to familiarise themselves with the questions and give more elaborate responses during the interview sessions. An open discussion at the end of each session was encouraged to capture interviewees' comments and emphasise on issues that interviewees deemed important. Discussion sessions where applicable were used to clarify information found in documentary evidence. Each interview session on average lasted between thirty to forty-five minutes, and all the interviews were tape-recorded.

The other key source of data was primary documentary evidence. This included minutes of relevant meetings, internal correspondence on the case and written reports. The documents provided not only a mechanism for constructing a chronology of key events but also extra data that participants interviewed had omitted. In addition, the documentation enabled us to validate and crosscheck what participants had expressed during interviews, thereby using it as a means of triangulation.

3.3 Data Management and Analysis

Before analysis could proceed, all the data collected had to be prepared and managed. A research database was created and was used to store all documents deemed appropriate for storing. These included document summaries and coded texts which eased reference to data.

The voice data collected during the interview sessions was listened to repeatedly and transcribed to textual data (transcripts). Despite the interview transcripts producing large amounts of textual data, data reduction was achieved by the use of a coding strategy. Guided by the adopted framework and the interview guides, a set of codes was developed prior to data collection. This set of codes was modified as the analysis progressed. Coding, according to Miles and Huberman [1994], is analysis and forms the first steps to an analysis of qualitative data.

Similarly, for the documents collected, each was read and the contents were summarised to capture essential data. Concepts that were frequently emerging in the texts were interpreted as key issues. These various categories facilitated insights, the comparison and the development of thematic analysis.

The second phase of data analysis involved data transformation of the collected data and working with it to create an "authoritative written account" of the case. Data analysis occurred simultaneously with data collection and was an iterative process.

The case data represented here is a portion of a wider Doctoral research, conducted to study the implementation of an information system in a case HEI, over a period of ten years. The case institution is referred to as Hekima, and the implementation of the Student Management System (SMS) is the focus of this paper

4. CASE STUDY -SMS ADOPTION AND ASSIMILATION (MID-2002—2006)

4.1 SMS Deployment

Earnest deployment of Student Management System started immediately after the completion of its development with three key activities: data migration, training, and a workshop held for Hekima's management board and directors of schools.

The first training was directed to specific users from the central administration who were directly involved with the nominal roll and the examinations modules of SMS. This group of users was trained on not only the operations of the modules but also technical aspects of report production using the ORACLE platform[†]. Although the training was sufficient to perform tasks such as updates and printing of pre-formatted reports, the users perceived the training as inadequate as they could not perform minor changes to the data such as change of dates on transcripts before printing and had to keep on relying on the developers for support. Said one user:

> *People said ORACLE is high level but maybe I needed the basics on how to change minor things such as how to change the years from one to another…I might try and then mess the data, yet with some training I could work well.*

Training sessions were mounted where all the central administration's academic section middle managers and schools' administrators were trained on the nominal roll and examinations modules. The developers doubled up as the trainers and all training sessions were mostly carried out at the IT function premises or student computer laboratories. In the early stages of implementation, the users trained did not have computing facilities in their offices to try out what they had been taught. As explained by an

[†] ORACLE report production tools used were the in-built reports and query-builder. These tools need some basic understanding of the Relational Database concepts.

examinations officer, "Initial training was not adequate; some of us had no access to computers...you could not practise what you trained in the first initial training."

Although the IT function facilitated basic computer literacy training for Hekima's top management, the same basic computer literacy training was not available for the envisaged users of SMS. The trainers made an assumption that staff who attended the training on the operation of Student Management System were computer literate, an assumption that later on became costly. Further, a training needs analysis for the envisaged users was not carried out prior to the training, leading to a situation that presupposed that the system implementers had adequate knowledge of the training needs.

Although the initial training created awareness and exposure for the middle managers, who later on became computer literate, the management role of this cadre of staff was not catered for in the system, or as explained by an admissions officer:

> *We would go for training and be taught how to key in data; it is not I who keys in the data…Management were not trained how to use management reports. Most of us in management are not using SMS for management reports, to assist as a basis in making decisions, and at our levels, that is what we should be doing.*

The third session of training was mounted for all users who would be involved in the first online registration process. Each School was required to appoint persons who were computer literate for the two-day training on SMS operations, and also, all IT function staff was trained to assist the users during the registration process.

Training continued after the first registration process that occurred in October 2002. All middle managers comprising administrative registrars from schools were invited for training in readiness for student course registration in the schools. This training was deemed crucial as the administrative registrars were directly responsible for student records at the school levels. Unfortunately, at the supervisory level, the administrative registrars could not perform the updates role and some opted to train clerks in their schools to perform the updates thereby causing varied results.

Contrary to the views of users on the issue of the appropriateness of the training, the IT function explained it was driven by the need to impart adequate training to perform the next job that included mostly operational work of data entry and the production of pre-specified reports. As explained by the IT Director and the former Project Manager, this approach to training was attributed largely to limited human resource; a situation that changed with the added human resource committed to the SMS project.

Training continued to be conducted, especially in 2004, after the redevelopment of SMS using web technologies. By the end of 2004, and after the third registration process, staff from schools that had adopted the Student Management System were fully trained. With a critical population of users trained, training continued to be mounted on demand, on the request by schools.

4.1.1 Workshops and School Academic Boards

Hekima's management board and directors of schools attended a two-day workshop in September 2002. The workshop's objective was to discuss student academic and financial records management, including the use of ICTs in Hekima. The SMS development committee used the workshop to get critical policy issues discussed and solutions recommended for implementation by middle managers. An example was the regularization of self-sponsored students' admissions to only two intakes a year that eased the management of academic processes in the central administration units. Academic processes and delays caused by schools were illustrated during the workshop and their effects on records management clarified. The SMS developed was demonstrated and its interactions with Hekima's policies, business processes, and delays in information flows illustrated. In summing up the workshop, the Chief Executive commissioned the Student Management System and asked all schools to adopt SMS for efficiency.

As several other workshops within the university were organized, the SMS development team was invited to present progress of implementation and demonstrate the operation of the system.

The growth of the ICT infrastructure in Hekima necessitated the devolvement of ICT services to the schools and, in due time, as information and communication technology issues became critical to the schools, the IT function staff were required to attend School academic board meetings to respond to ICT issues. In some instances, where such information and communication technology issues concerned the management of student records, the IT Project Leader in charge of SMS development would be invited to demonstrate SMS to the board members. Indeed, social relationships created in the course of providing

ICT services within Hekima also provided a means by which some users would feel obliged to listen to the SMS "story." The slow response to actively use the SMS according to the IT Project Leader was the perception that the implementation of SMS was an IT function project. However with the adoption of Results Based Management (RBM) at Hekima in the later years of the implementation effort, all schools were required to adopt and use SMS for students' records management. This requirement pushed late adopters of the SMS to comply and report progress as part of performance contracting within the University.

We illustrate the adoption of SMS at Hekima using two units, Central Administration and School A.

4.2 Adoption at Central Administration

The central administration middle management officers were involved in the development of the SMS and hence adoption and use of the SMS was more acceptable. This acceptance was mainly because the middle managers, especially the admission, examinations, and finance officers had been exposed to the benefits of computer systems from the earlier versions of COBOL and dbase IV systems. Further, the finance section was running computerized payroll services.

The finance section, driven by the need to produce accurate financial reports concerning student fees, continued to work with the developers towards improving the fees module immediately after the first online registration. This included counter-checking fees transactions against the manual receipts for accuracy, the development of the necessary functionalities, and the training of staff from the section. The collection of fees for government-sponsored students was under the central administration's finance section. The Finance Officer, who headed the section, was not only conversant with computer-based applications but was also required to produce financial reports related to students' fees. This background provided an environment in which the Finance Officer took over the championship of the fees processing module with ease. By July 2003, he was spearheading meetings concerned with this module.

Although initially after the introduction of the online receipting there were some users who preferred the manual receipting, it however dawned on them that their supervisors' and indeed the top management's need for reports on collection of fees as the registration of students was on-going and the students' demand for fees statements would not allow any excuses. By the end of 2004, all finance officers in Hekima were using the fees subsystem and, by 2005, they were very well versed with the fees subsystem and used the system for fees transactions. As observed by the SMS Project Leader, this single module was quite successful; he attributed this to users achieving immediate tangible benefits – increased revenue collection.

The initial adoption of the academic modules (Nominal Roll, Course Registration and Examination Processing) by the central administration academic section was acceptable due to the involvement of most administrators, except the head of section, the Academic Registrar, who was not very interested in the whole process. Some staff from the examinations section, despite having been involved throughout the development of SMS was more uncertain. For a start, the system introduced changes in the work roles of the section, in which the section was required to relinquish data entry of student marks to be done at the source, the schools. The concept did not settle well initially, but on realization that the section was not going to cope with the amount of work and the immediate benefit to their workloads, the changes in role was acceptable. One examinations officer said:

> *One of the things which made us sceptical on this was the data entry of the marks, from time immemorial the marks would come here and we work on them ourselves. Nevertheless, later it emerged that with the large numbers of data from the schools and we only had two data entry clerks, we were not going to manage and that was the only way out.*

The notion of data being safe in a shared centralized computer was a new idea for the section, and it took time for the users to shift their belief system and trust the security mechanisms within the ORACLE RDBMS and the SMS. Prior to this, the section stored marks in offline hardcopies and in diskettes that would be loaded when needed for the production of transcripts. Copies of transcripts printed would be kept in student files and stored in the archives.

Unlike the fees processing module which was adapted and owned by the finance section wholly under the guidance of the head of section, the Finance Officer, the academic modules of the system (Nominal Roll, Course Registration and Examination Processing) were not owned immediately by the head

of section, the Academic Registrar. While the Academic Registrar sent his immediate deputy and senior administrators to the system development committee and various meetings concerning SMS, his participation and ownership of the process was clearly missing. One admissions officer blamed the slow pace of implementation of additional requirements to the lack of participation of his boss.

Interviewees had various explanations for the observed lack of leadership by their boss. Some participants attributed it to his personal character, while others were of the view that he was about to retire and had never used computers directly despite having one in his office and, therefore, he was not interested in the system. Despite the leadership gap, the SMS operations in the central administration's academic department continued to be championed by the middle management who rose up the ranks and became in charge of the section.

4.3 Adoption in School A

School A had always lagged behind in the processing of examinations, and hence the course registration and examinations subsystem was crucial in operations at the School. Reports from the data migration exercise carried out to facilitate the initial deployment of the course registration and examination processing modules indicated non-availability of data due to non-submission to the central administration's examinations section. In the early developmental stages, the School was identified as one where piloting would be done due two key factors. One, the School had the largest number of students; approximately 30% of all Hekima students, and, two, the School's students were edgy on the delays of examination results. The previous SMS Project Leader, responsible for development of the Students Management System indeed sought to assist in the collating of the available marks to Excel format for migration. While initial visits to the School were welcomed by the administrators, the Director of the School was not supportive of any efforts. On realization that some student marks had been migrated to SMS, the Director barred the SMS Project Leader from visiting the School offices and access to the computer for SMS-related work was subsequently denied. Efforts to put more computers to an available room where staff would work on the students' data were thwarted by the Director, who locked up the room. The resistance by the Director later emerged to have been driven by the motive of engaging a private contractor to do the computerisation of students' records in the School.

However, by May 2003, the School was under new leadership and through interactions with the School staff, the new Director got to learn about the Students Management System and made further enquiries from the IT function about the SMS. That marked the turning of events in the School and paved way for a deliberation meeting between the SMS team and the School in May 2003 that charted the way forward for the Students Management System implementation in the School. The Director described his motivation for adopting SMS as a tool to run the School more efficiently and provide students with results. The inspiration for use of the Students Management System was also necessitated by the transfer of the School administrator who was well versed with the practised examination rules and regulations and that were not documented, making the task of dealing with student records more difficult for the Director. At the same time, the Director realized that the huge challenges in dealing with manual procedures were an enormous task especially with the increase of student numbers.

A working team comprising staff from the School and the IT unit embarked on data migration and validation while the Director of the School facilitated the process by motivating his staff and providing resources such as the creation of a student records' office where students' data-related activities were carried out using shared resources. Although computing facilities initially were not enough, this did not deter his efforts to be efficient with the meagre resources. He said:

> *We did not have enough facilities and even now we do not have enough, the School is not completely networked and the computers are not enough. However, I did say that we must make a start with the few facilities that we have.*

The users at the School gained additional training and support as they worked with the IT staff, hence gaining more confidence. These initial efforts were geared towards government-sponsored students, and transcripts for the School became easy to produce. This lessened the pressure on the Director from students and Hekima's management, and subsequently reduced tendencies of chaos by the School's students because of late examination results.

Nevertheless, resources and human-related problems affected the examinations process and hence reflected in the timeliness of report production. Key among them were delays in the submission of marks

from the departments, partly due to the examination process itself that required chairpersons of each department to get results from each member of staff and collate the results for onward transmission to the Director's Office for further processing through SMS[‡]. The Director expressed his experience, saying: "Sometimes you find a chairperson who is not able to actually do their work in the department and that delays us."

At the departmental level, lack of resources, especially PCs, made the implementation efforts slow. To enhance the process, the School planned to acquire more PCs for distribution to each department for the purposes of consolidating students' records at that level.

The turnaround of the School, from being inefficient, to a situation where results were available at the end of each semester, something the School had never done before, was a major achievement. The use of the Student Management System in the School was now considered a normal practice, with the manual ways replaced by and the examination rules and regulation incorporated into SMS.

5. ANALYSIS AND INTERPRETATION

5.1 Managerial Interventions

The university top managers and unit managers that embraced SMS, in varying efforts, tried to mediate the implementation process in various ways. Five themes emerged as mechanisms by which the various actors involved in the implementation process intentionally used to enhance and create an enabling environment in the course of the case study period. These intervention mechanisms were training and support, the recruitment of additional staff, the enhancement of computing resources, mandating and motivating the use of SMS, and the monitoring of progress of the implementation process. The management of changes brought about by the Students Management System were mediated by the use of participative approaches, seminars, demonstrations and workshops. These interventions are outlined below.

a) Training and on-site support: The general view of the training provided was that of inadequacy with respondents calling for the need for continuous training, especially in the early stages of SMS adoption and use. The impact of the inadequate training was evident in the critical events of students' registration; especially the first student registration that took place in October 2002, and continued to emerge during such events, leading to a lack of confidence in use of computers and the emergence of data errors. To overcome this challenge, training sessions were scheduled a few days prior to the annual registration process at the start of each academic year. These training sessions continued to be carried out.

   Despite the emphasis laid on and effort put into training in the early years, a recurring issue that affected the quality of the training was the unavailability of computers for people to use once they returned to their offices. The IT department carried out the training in anticipation of availability of computing resources which in some instances were delayed due to the procurement process. The trained staff would quickly forget how to perform tasks without access to a computer. They would require a refresher course on the processes in SMS, leading to the implementers having to train a person several times. Sometimes the implementers would need to provide more personalised training as users performed the tasks with the computer. This was not an efficient way of utilising the scarce technical human resources. Although the IT department recognized the need for training, the lack of adequate technical staff, where SMS developers doubled up as trainers, forced the department to adopt a need-based training approach. This only entailed a person being taught how to operate the system to perform the task required. The users perceived the training offered as inadequate as users had to rely on calling IT staff to sort out small problems as they used the system. In addition, the inappropriateness of the initial training in some scenarios, especially where the middle management was trained on operational tasks, did not

[‡] The devolvement of SMS to capture data at source by the lecturers was planned to take place at a later phase

entice middle managers to use the system. The non-alignment of the training with the availability of computing facilities hindered the learning of the SMS while the inadequate training produced incompetent users, thereby slowing acceptance of SMS in the initial stages of organizational assimilation.

The increase of human resource capacity in the IT department changed the training approach. After the classroom training, on-site support was introduced, and staff continued training users at their workstations as they used the system, creating user confidence in the use of the system and providing opportunities for more clarifications on the work flow as implemented in SMS. The provision of on-site support enhanced the skills of the users, leading to routine use of the Students Management System. At the close of the case period, it was observed that most of the SMS users were competent, and training sessions continued to be mounted as need arose with refresher courses for persons affected by transfers from one unit to another.

a) Recruitment of additional staff: Starting with one technical member of staff in the early years of SMS development, the employment of more personnel in the IT function who were later dedicated to the implementation of the Students Management System improved the process. Despite this, staff in the IT unit was not adequate for all ICT-related activities in Hekima, and thus caused deployment of SMS to be carried out one school at a time, slowing the pace of the roll-out of the system. The hiring of temporary staff, facilitated by various unit managers, to perform massive operational tasks when the need arose, such as the data capture in the central administration's examinations section, enhanced the adoption of SMS and showed commitment to the system by the concerned managers in the process. In other units, the managers restructured work tasks to cater for the frequent and continuous operational tasks that were under their mandate. Examples of these tasks included the redefining of roles for secretaries in the central administration's admissions section and clerks in the schools who after undergoing training took up data capture and validation roles in their respective units.

b) Enhancement of computing facilities: Although in the early years of the Students Management System implementation, the available computing resources, especially PCs, were cited as a hindrance to acquiring ICT skills, the IT function tried to distribute the resources equitably. This was achieved, especially after the first registration, by distributing the available computers equitably to schools to facilitate the progression of SMS operations. All officers involved in the system operations preferred to have PCs in their office, and where that was not possible the creation of centralized students' offices with shared resources was implemented as an alternative. However, as the university's exposure to the use of SMS and other ICT areas expanded, such as the use of email and internet, access to PCs became much easier as departments purchased them for their members of staff. By 2006, all staff required to use SMS had access to a PC in their offices.

The continued enhancement of central computing resources, especially the servers, notably after the second online registration and again after the fifth online registration, reflect interventions to increase the capacity of ICT facilities within Hekima to accommodate the increasing demand of the Students Management System.

(d) Mandating and motivating use: The Chief Executive Officer had knowledge about the need of SMS, especially the benefits of registration and fees collection, and mandated the use of the online registration and the fees processing modules in the central administration's units. Similarly, the later leadership in various units sent clear messages about the change to SMS, thus mandating use. Although mandating use led to the adoption; the acceptance and use of the Students Management System were enhanced by the ensuing support provided by the authorities such as logistical and resources accorded for the adoption to be fruitful.

A general incentive system in the university was lacking, and there was no punishment for lack of use of the SMS. However, during the annual registration participants in the exercises were rewarded with some monetary payments, while in some schools overtime work was paid. These rewards were not inducements for the system use. The motivation for the use of SMS stemmed from individual users especially where users who were ICT literate, and their leadership in the various units such in School A. For example, the Director of School A, who knew about the business need of the system, used his leadership skills to motivate staff by supporting them in

organizing and following up on problematic areas raised and keenly followed and monitored the process.

c) Monitoring and evaluation: The absence of a university-wide monitoring and evaluation schedule was perceived as a weakness in the implementation process, and resulted in difficulty of getting progress feedback of the total project at the university-wide level. Although the SMS team at the IT function submitted reports indicating how the schools were progressing in the use of the system and in the examinations data captured in the SMS, the general lack of an overall implementation time schedule made evaluation of the progress difficult. However, in the later years, especially with the adoption of Results Based Management (RBM) systems at Hekima and the automation of students' records as one of organizational capacity development indicator provided a means by which the overall computerization process could be evaluated. The extent of the implementation of SMS in schools was one of the key performance indicators in the Performance Contract between the University and the Units and this helped in the adoption of SMS, especially by the later adopters.

d) Change management interventions: Change management interventions were evident, and included workshops where participation of the various participants from the SMS development committee elicited challenges involved in the implementation process and proposed solutions for the adoption of the system where possible. IT staff were invited and demonstrated the system functionalities expounding the advantages of the system while bringing out the various roles of the different stakeholders.

The implementation of the SMS adopted participative approaches such as the involvement of the users and holding problem-solving meetings with users. However, a key component of managing change seemed to lack in the early phases of SMS development - communication to the university community. This lack of communication changed once deployment was started with frequent communication to other stakeholders and not just the development committees. However, technical changes tended to be a preserve of the IT function staff and were not shared much with the other users. A typical example was the decision by the IT staff to overhaul the client-server environment without involving the stakeholders. Although there were good technological reasons to do so, some interviewees observed that their input was not sought and they only found a replacement of the previous system. Thus communication emerged as critical to building interest in and support for the Students Management System. It was during some of these sessions of communicating to users the strategic agenda, operational issues and expected results from SMS, in a workshop for example, that social relationships were created between the implementers and the users that contributed to a commitment to the SMS project.

The presence of a university-wide plan for the implementation of SMS was not there, and the change management model that emerged from the case study pointed to improvisational, responding to change as the implementation process proceeded.

No structural changes at Hekima were implemented as a result of SMS, but several changes were found in the practices or processes, culture and the technology itself (SMS). Mechanisms through which the changes were recognized included system demonstrations, workshops and online registration review meetings and actions agreed upon in these forums taken by the implementing unit. User training sessions were also another key avenue for managing change. By training the users and, in the later years of implementation, providing on-site training and support smoothed the changing work practices.

5.2 Context as Enabling and Constraining Managerial Actions

The deliberate actions to mitigate challenges within the implementation context and manage change within the case demonstrated a closely intertwined relationship between the actions of the managers on one hand and the general context on the other hand. Indeed, the intervening actions emerged out of the need to reshape the context and make it more suitable for the adoption and the assimilation of SMS to occur, while the context constrained those actions. This relationship was illustrated by the training and support interventions which, while geared towards enhancing the user skills set, were constrained by the availability of computing resources. Likewise, the development and enhancement of the computing resources was driven by the availability of financial resources. Due to this, managerial decisions such as

the phased implementation which was aligned to the development of the ICT infrastructure, continuous scheduling of training as a result of continuous enhancements of access to computing resources was shaped, driven and influenced by the context. Workshops and seminars were fundamental change intervention mechanisms effectively used in Hekima. These created forums where discussion about SMS were carried out and may be viewed as forums that created windows for consensus building. Indeed, negotiation and consensus building have been identified as social logics embedded in the cultural values of African societies [Olivier de Sardan 1999].

The relationship between the actions of the managers and the context displayed a dynamic interaction between the various organizational structures, especially resources, culture and managerial actions, thereby linking factors and the process. In Gallivan's theory, this dynamic relationship is linked to facilitating conditions, where the context is viewed as both enabling and constraining the technology implementation process. From this interpretation, we illustrate that the organizational context shapes managerial interventions and decisions (see Table 2). This finding is indeed similar to the findings of various studies that exemplify the importance of the implementation context such as Walsham [1993], Walsham and Waema [1994], Avgerou [2001], Walsham [2001], Krishan and Walsham [2005], and Walsham and Sahay [2006].

Activity	Enabling Context	Constraining Context	Managerial Interventions
SMS Deployment	• IT Leadership • Availability of Technology • Adoption of Results Base Management towards end of case study period	• IS/ICT knowledge barriers • Inadequate technical skills • Inadequate project management skills • Inadequate ICT human resource • Lack of an overall monitoring and evaluation schedule of implementation efforts	• Continuous ICT training • On-site Support • Recruitment of additional human resources • Participative approaches (Workshops, Presentations in Academic Board Meetings)
Adoption at Central Administration	• Technology adoption leadership in some units • Availability of computing infrastructure within the Central Administration • Leadership mandating use ICT technically skilled human resources	• Lack of technology adoption leadership in some units • Prior history of use of computerized systems	• Participative approaches • Use of Middle Managers to mitigate leadership gap
Adoption in School A	• Technology adoption leadership • Continuous motivating use of SMS • Availability of keen users	• IS/ICT knowledge barriers • Inadequate technical skills • Inadequate computing resources	• Aligning the secondary adoption and assimilation of SMS to the availability of computing infrastructure • Continuous user training and on-site support

Table 2: Illustration of enabling and constraining context and the Interventions used

6. CONCLUSIONS

A general conclusion is that the implementation process must be understood in the context within which it occurs. The case illustrated the organizational context shaping the managerial interventions and

actions. This is in agreement with the literature which has stressed the importance of context [Heeks 2002; Avgerou 2001]. The implementation process results in organizational change that requires continuous change management mechanisms. This conclusion, again, is indeed in agreement with observations in literature [Orlikowski and Hofman 1997; Macredie and Sandom 1999; Cunha and Cunha, 2003] that organizations often require continuous actions in response to change outcomes associated with IS implementations. This is typically due to the continuous interaction of the technology and the social context that result in planned and unplanned changes. Additionally, challenges such as knowledge barriers, lack of resources are evident in adoption of new technologies and require interventions such as training, hiring of staff with the appropriate skills for the implementation process to proceed.

In this paper we used an enhanced Gallivan's framework [Gallivan 2001] and specifically the managerial construct to illustrate the relationship between organizational context and the IS implementation process. We have presented a case study that demonstrates the efforts of implementers towards creating and enabling environment for successful implementation of a case application in the higher education in a developing country. Implementation and use of IS often results in changes, creating potential for conflict and resistance, and hence using appropriate managerial and change intervention mechanisms improves adaptation to the information system.

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Optimizing Internet Bandwidth In Higher Learning Institutions: A Case Of Sokoine University Of Agriculture

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Abstract

Internet connectivity is very crucial for Higher Learning Institutions in order to fulfill their mandates of training, research and consultancy. The Internet connection is important for (i) communication and collaboration (ii) research and consultancy (iii) courses and content delivery i.e. academic management of courses and access to educational resources. One of the challenges facing higher learning institutions in developing countries is the low bandwidth leading to low Internet speed. This situation is aggravated by the fact (i) these countries have poor infrastructure for Information and Communication Technology (ICT) (ii) equipment, software and bandwidth are acquired at very high price in comparison with developed countries (iii) the acquired bandwidth is poorly managed due to limited number of skilled personnel. This paper presents lessons learnt from Sokoine University of Agriculture on how to face the mentioned challenges of poor bandwidth optimization and management (BOM). It also proposes a way forward for management and optimization of bandwidth. The concluding remark is that the use of tools for bandwidth management and optimization from Free and Open Source Software in developing countries is recommended. Furthermore, purchasing more bandwidth for SUA in near future is inevitable.

Categories and Subject Descriptors: K.4.2. [**Computers and Society**]—Social Issues; K.4.3. [**Computers and Society**]—Organizational Impacts; K.6.1 [**Project and People Management**] - *Life cycle, Systems development;*
General Terms: design, data management
Keywords: Internet, bandwidth, management, optimization, tools, Free and Open Source Software, Higher Learning Institutions in developing countries

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1. BACKGROUND INFORMATION

Sokoine University of Agriculture (SUA) has two campuses, namely: main campus and Solomoni Mahlangu Campus (SMC). Computer Centre was established in 1993 with various functions including coordination of the computerization of the university activities; planning, establishing and maintaining the Information and Communication Technology (ICT) infrastructure and develops manpower responsible for ICT [SIPG, 2002]. Computer Centre has three computer laboratories for more than 8000 students.

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Currently, there are 500 computers connected to the SUA Local Area Network (LAN). The Internet connection is hooked to two Internet Service providers (ISP). One is an International ISP (IISP) called "Constellation Company Limited" and the other local ISP (LISP), is Tanzania Telecom and Communications Company Limited (TTCL). The Internet Connectivity from Constellation Company Limited is shared by 8 institutions. The bandwidth obtained from IISP is 2 mbps for downlink and 256kbps for uplink; while for LISP is 64kbps for downlink and 64kbps for uplink.

The connection for IISP is through shared mode via Very Small Aperture Terminal (VSAT) while for LISP is of dedicated model via leased line. SUA's mail service uses the bandwidth from LISP while the other Internet services (such as Web i.e. WWW or World Wide Web) use the bandwidth from IISP. The problem which SUA experience from shared model is that during peak hours when all organizations are using Internet, the bandwidth becomes saturated. Thus, the available bandwidth at SUA becomes limited. This is has caused some departments to have their own Internet connection via VSAT. Examples of departments which have their own Internet connectivity are Soil and Water Management, Microbiology and Forestry Engineering. The tendency of the departments having their own Internet connection does not solve the problem for long term. Instead those solutions do add more cost for the Institutions and there is mismanagement of bandwidth. The reason for this is that those departments have no skilled staff to manage their network and they are unaware of dangers caused by poor management of bandwidth. Furthermore, when the funding period of the projects supporting the Internet connectivity finishes it will mean even the departments Internet connections must end. Moreover, this trend of individual department being hooked by private Internet connectivity shows that the ICT Policy and Guidelines are not being followed well. The ICT Policy and Guidelines states it categorically that Computer Centre will be responsible for supporting Internet services for the whole university [SIPG, 2002].

2. PROBLEM STATEMENT

When the Internet was first setup at SUA there was no enough qualified staff to design, develop, implement and maintain the LAN. This resulted into poor design, improper development and mismanagement of computer network. Also, there were no proper procedures to handle computer network, Internet connectivity and security related problems. There was no proxy server for caching purposes. Mail servers and routers were poor installed and this lead to misuse of bandwidth because of the peer-to-peer traffic, streaming of audio and video, spam (i.e. junks), computer viruses, computer worms, etc. Peer-to-peer allows file sharing around the world to connect to each other. These problems, among many, caused SUA mail server to be blacklisted. Blacklisting of server happens when the server allows open relay hosts (mail servers that accept connections from anywhere) and open proxies (proxy servers that accept connections from anywhere) [Venter, 2003].This in turn made some Internet services from SUA being unavailable. When the mail server was blacklisted the e-mails bounced when it was send to recipients using yahoo, Gmail and hotmail mail services.

Internet services provided by Computer Centre to the university community are based from the following servers: Network Address Translation (NAT) Servers (RedHat enterprise), Domain Name Server (DNS) (RedHat enterprise), E-mail and Web Servers (Fedora Core 3), Firewall (RedHat enterprise), Gateway (RedHat enterprise) and Dynamic Host Configuration Protocol (DHCP) server. For more clarification about Internet services read the following Table 1:

Internet Services	Comments
Electronic mail	Simple Mail Transfer Protocol (SMTP) to/from the Internet
	Post Office Protocol (POP) access from the Internet
	Internet Message Access Protocol (IMAP) access from the Internet
Web	Access from SUA network to Internet
	Hypertext Transfer Protocol (HTTP) from Internet to web caches
	HTTP from priority websites to web caches
	Hypertext Transfer Protocol Secure (HTTPS) from Internet
DNS	DNS requests and replies
	DNS zone file transfers

Website updates	File Transfer Protocol (FTP) access for upload and download

Table 1: Internet services at SUA

Thus in order to address the above described problems, there is a need of implementing the bandwidth management and optimization (BOM) tools. In addition, the recommendations mentioned by Mawazo and Ruhusa [2009] need to be taken into considerations during the implementation of BOM. The suggestions were to (i) replace core switch (distributors) (ii) install new manageable layer three switches (iii) replace uplink switches (iv) place new manageable layer two switches (v) create virtual LAN infrastructure (vi) purchase commercial firewall with network antivirus (vii) procure more bandwidth for Internet Services (ibid.).

3. METHODS

3.1 Tools used in BMO

As stated early from the situational analysis that we realized the need for BOM then we identified how the implementation will be done. Thus, bandwidth was managed and optimized using Free and Open Source Software (FOSS) tools [Benvenuti, 2009]. One reason why FOSS tools were chosen was to cut cost. The tools were implemented for classification, shaping, scheduling, policing, marking and dropping the traffic of packets as proposed by Wambua [2009].

The FOSS tools which were adopted for BMO implementations were first evaluated. After evaluation tcpdump and Multi router traffic grapher (Mrtg) was adopted (see Table 2).

Tool	Function	Description
tcpdump	Packet sniffer	Log traffic between hosts
Mrtg	Monitors the traffic load on the network links using SNMP	This tool provide a visual representation of inbound and outbound traffic
ping	Spot check for host connection	It uses ICMP packets to contact a specified host and tells how long it takes to get a response
traceroute	Remote connectivity checker	Used to find the location of problems between different computers and any point on Internet

Table 2: Tools used during implementation of BMO

During evaluation of tools the network traffic were generated and measured using the identified BMO tools. The BMO tools were installed in different servers such as mail server, DNS etc. These servers consist of traffic sources and sinks from a switch, VSAT connections and router devices. The interfaces (see eth0, eth1, eth2, eth3 in Figure 1) of these devices were connected to different servers. Eth0, Eth1, Eth2 and Eth3 stands for Ethernet number 0, 1, 2 and 3 respectively.

3.1.1 How analysis of traffic was done from different interfaces

First, we configured MRTG and setup it to monitor the network and link utilization. Second, we configured the firewall to prevent access to/from remote sites based on Internet Protocol (IP) address ranges, port numbers, and individual sites. In addition, the proxy was configured to filter HTTP traffic forwarded from firewall.

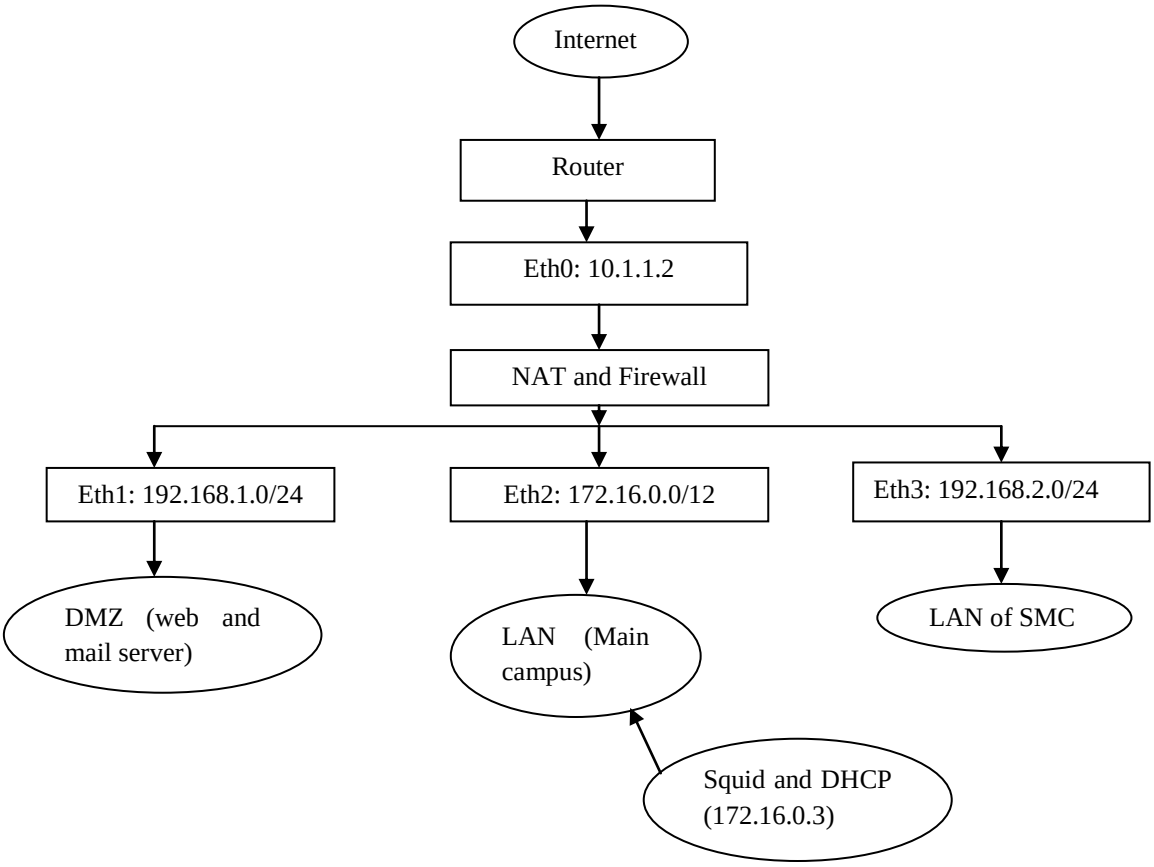

Figure 1: Network architecture of SUA [Adopted from Magesa and Luhusa, 2009].

From Figure 1, our Firewall has four Ethernet interfaces: eth0, with the IP 10.1.1.2, faces the outside; eth1, with the IP 192.168.1.0/24, faces DMZ (consisting of Mail and Web Servers); eth2, with IP 172.16.0.0/12, faces Local Area Network (LAN) of main campus; eth3, with IP 192.168.2.0/24, faces the Solomon Mahlangu Campus (SMC). The link between Main Campus (MC) and SMC is through wireless link.
Therefore, in this case, the example of rules contained in our firewall is as follows:

- Drop packets arriving at eth0 whose source IP is within 192.168.1.0/24 or 192.168.2.0/24 or 172.16.0.0/12

The advantage of the above rule is that it supports anti-IP-spoofing. This means all spoofed IP (forged source IP) addresses can easily be detected. The IP spoofing is a common network attack which pretends to send packet with IP addresses as if they come from the trusted (internal) networks.

In order to identify the cause of the bandwidth misuse the traffic of the Internet connection was analyzed using MRTG and the results, which was obtained from MRTG, (as shown in Appendices) were used as baseline. The cause of slow Internet connection was established from the baseline. The information obtained was used in the implementations of BOM. Furthermore, the problems in the network configurations of the university's servers were identified. In addition, the computer and network security techniques and the software in use were examined. Finally, user awareness training which have already been undertaken by Computer Centre staff to the SUA community were investigated if they meet the current challenges facing Internet connections at SUA.

In a project of Vlaamse Interuniversitaire Raad (VLIR) which involved universities from Southern

of Africa and from north (i.e. Belgium), the capacity building of our three staff was undertaken at MSc. level. In addition, some of our staff participated in 5 workshops which were meant for capacity building in all matters related to BOM [Mantell and Abagi, 2008]. The training and workshops range from theory to practical aspects of BOM. The topics taught were policy formulation for BMO, practical guide to BMO using FOSS, installation of proxy (squid), web server, mail server and DNS. The training conducted by VLIR through International Network for the Availability of Scientific Publications (INASP) helped the Computer Centre staff in network management, monitoring and security administration using FOSS tools [Venter, 2003].

Some of the network management, network monitoring, network security activities which were done at SUA are:

a) Firewall was implemented in our router.
b) Spam filter (using Spamassassin) and blocking some e-mail attachments (using Procmail) was installed at mail server.
c) Anti virus called Sophos Antivirus for the mail server was installed
d) Proxy server using Squid was implemented
e) Traffic shaping was introduced and BMO using FOSS tools was implemented

The results of the implementation of FOSS tools to monitor the SUA network are presented in the Appendix.

4. RESULTS AND DISCUSSION

The introduction of firewall and proxy server at SUA resulted to better Internet speed. This was reported from staff and students. User satisfaction probing was done by using open ended questions through staff mailing lists. The response from different stakeholders was they realized that before implementation the situation was worse (in terms of Internet speed) and after implementation, the Internet services improved.

The implementation of Procmail and Spamassassin helped to control the problem of spam (or junks e-mail) and thus, the IP address of our mail server which was blacklisted was removed from those servers showing blacklisted mail servers. Procmail and Spamassassin were configured to check incoming and outgoing mail viruses, spam and suspicise e-mail attachment (example those with .exe, sex.* file extensions). As results the viruses and spam/junks were no longer being transmitted in larger number consequently, the uplink traffic of SUA was no longer clogged. Hence, the overall Internet speed improved.

The implementation of the traffic analysis tools such as MRTG helped to optimize the use of our bandwidth. By using such tools the peer to peer traffic was under control and therefore, this improved the browsing behavior of our users since HTTP was setup to have high priority. One of the problems that we are still facing is that during peak hours of Internet utilization MRTG shows that the bandwidth at peak consumption is below the bandwidth bought from IISP (127.6 kb/s (49.9%). The reason for this is due to the shared link thus sometimes other 7 institutions connected in the same link are utilizing more than the purchased bandwidth (see Figure 1 up to Figure 9 in an appendix).

Figure 2 and Figure 3 in the appendix reveal that there is too much traffic during mid night at SUA Internet link; this signals virus activities, spam/junk e-mails as well as malicious codes. Also graph in Figure 2 shows that SUA internet link has more download traffics than upload traffics; this also signals lack of local content inside SUA network for outsiders to download from SUA. This in turn shows why we opted to implement cache server to resolve the issue of not having enough local contents.

Figure 6 in the appendix shows SUA Internet link saturate very quickly from 09:00 a.m. up to 23:00 p.m., this emphasis need for improved Bandwidth Management and Optimization as well as need to increase more Internet bandwidth.

Figure 8 in the appendix reveals that there are peer-to-peer connection using SUA Internet link, this signals that there are users with download managers software in their computers. These software enable heavy down loaders congest internet connection restricting internet access to other users and servers that need global accessibility.

Websites accessed by each user of our network was identified. We found that bulk of Internet traffic is peer to peer access and downloads of music, video and Anti-virus updates and access of free e-mail services (See Figure 11 in the appendix). Although, we acknowledge that peer to peer access and download of music, video and Anti-virus updates and free e-mail services might be important for academic

institutions (such as SUA) but, they fall under low priority in low bandwidth environment. This shows the importance of contextulising the solution of the problems related to BOM. Thus, the SUA management through Computer Centre established a policy which allowed our system administrators to block all websites which were not of SUA priority during peak hours. The website listed were: facebook, blogs, chatting applications, applications supporting peer to peer file sharing, gaming, pornography and video streaming.

Our results from this paper presents the experience of bandwidth management and optimisation problems and solutions from SUA which is similar to those reported from Addis Ababa University, Ethiopia; Malawi College of Medicine; the Multilateral Initiative on Malaria network (MIMCOM); University of Zululand, South Africa; University of Moratuwa, Sri Lanka, University of Dar es Salaam, Tanzania; Makerere University, Uganda; and the University of Bristol, UK [Venter, 2003].

5. CONCLUSIONS

Many universities in developing country which have low bandwidth are forced to adopt BOM tools from FOSS [Venter, 2003]. Gwynn [2006] identified that 59% of higher learning institutions in Africa do not monitor or manage bandwidth at all. This is an alarming situation and thus, calls for more researches related to BOM aspects. We have presented, in this paper, the experience of SUA's Computer Centre. We did explain the network related issues and how to implement the BMO using FOSS tools.

According to Weerawarana and Weeratunga [2004], FOSS is better suitable to be adopted in Africa environment for BOM since: (i) FOSS can cost less to acquire and run than proprietary software (ii) FOSS can ease the burden of software license management (iii) FOSS can be robust and secure (iv) FOSS can help discourage software piracy which is one of the major problems in Africa's software industry and (v) FOSS can be a useful teaching and learning tool in ways proprietary software can't match. Thus, the use of FOSS in university of developing countries has economic, social and culture advantages. Economic advantages arise from reducing the cost of procuring the software, reducing foreigner currency to buy the software outside the country and retaining the money by supporting local company involved in providing FOSS training. Social advantage arise from the software development methodology of FOSS where by software is produced for the people and by the people of different communities in the world. Thus the end product is owned by the whole communities. Culture advantage arises from the fact that any FOSS tools allow customization and localization as per culture values of the concerned society. Additional potential advantages includes increasing choice and competition among the stakeholders of software industry, positioning software as public good, increasing technological self reliance, reducing vendor lock-in, minimizing security risks, and cost savings.

Internet services access at SUA has emerged to be developing fast, and bandwidth management and optimization (BMO) appears to get due attention. With the large numbers of computers that are being added to SUA's Local Area Network (LAN), and the fact that the Internet bandwidth is already fully utilised, it would not be surprising if more bandwidth is purchased in the near future. This is in turn will necessitate future study to be conducted to investigate how we can migrate to a better Internet Service Provider (ISP) with affordable cost (i.e. within our budget).

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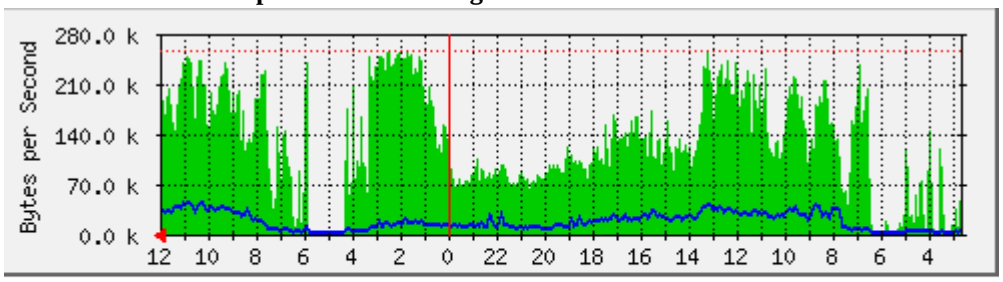
7. APPENDIX

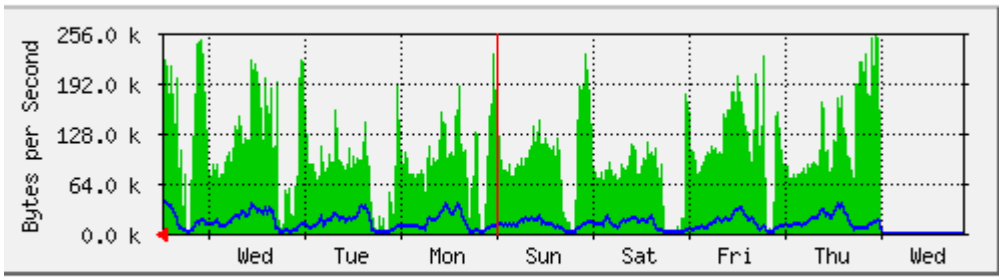
Results from BMO implementations using FOSS



	Max	Average	Current
In	254.7 kB/s (99.5%)	127.6 kB/s (49.9%)	222.2 kB/s (86.8%)
Out	44.1 kB/s (17.2%)	17.0 kB/s (6.7%)	33.7 kB/s (13.1%)

Figure 2: Traffic analysis using MRTG at 22 April 2010

'Weekly' Graph (30 Minute Average)



	Max	Average	Current
In	254.2 kB/s (99.3%)	106.6 kB/s (41.6%)	190.9 kB/s (74.6%)

Figure 3: Traffic analysis using MRTG at 22 April 2010

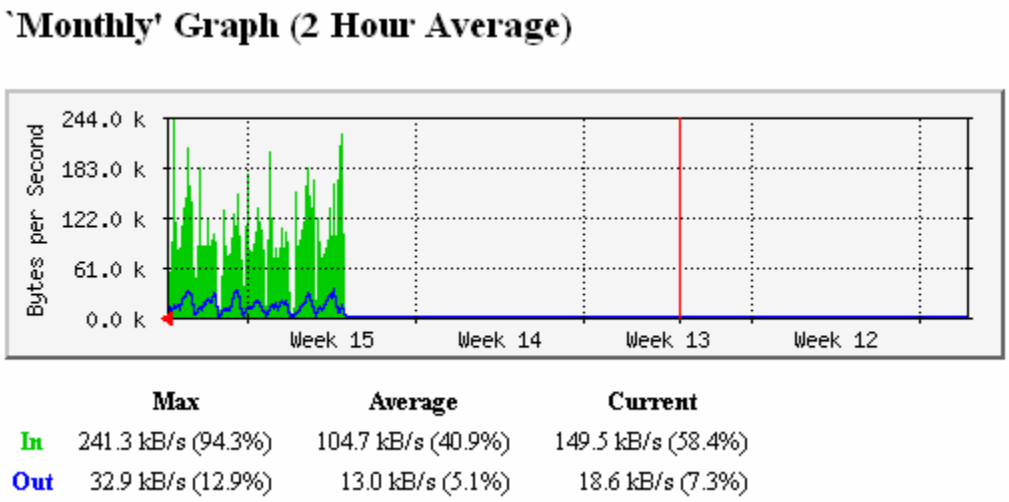


Figure 4: Traffic analysis using MRTG at 22 April 2010

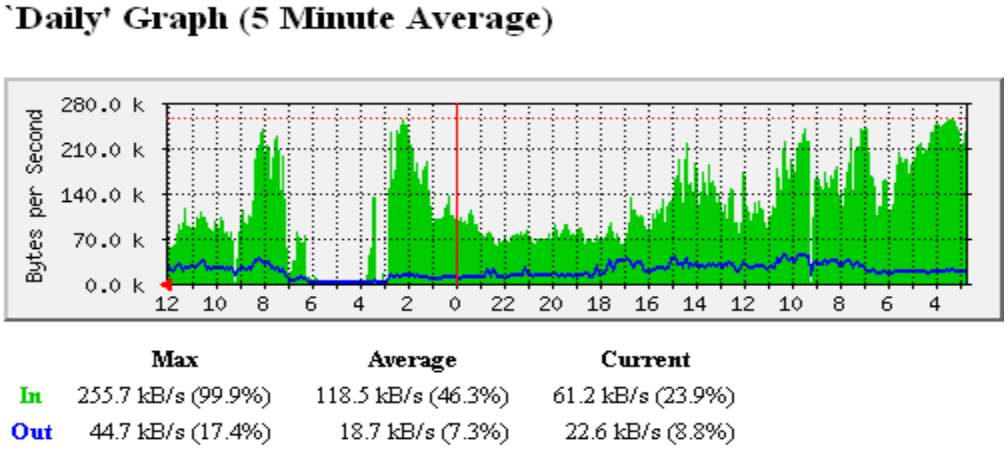


Figure 5: Traffic analysis using MRTG at 22 April 2010

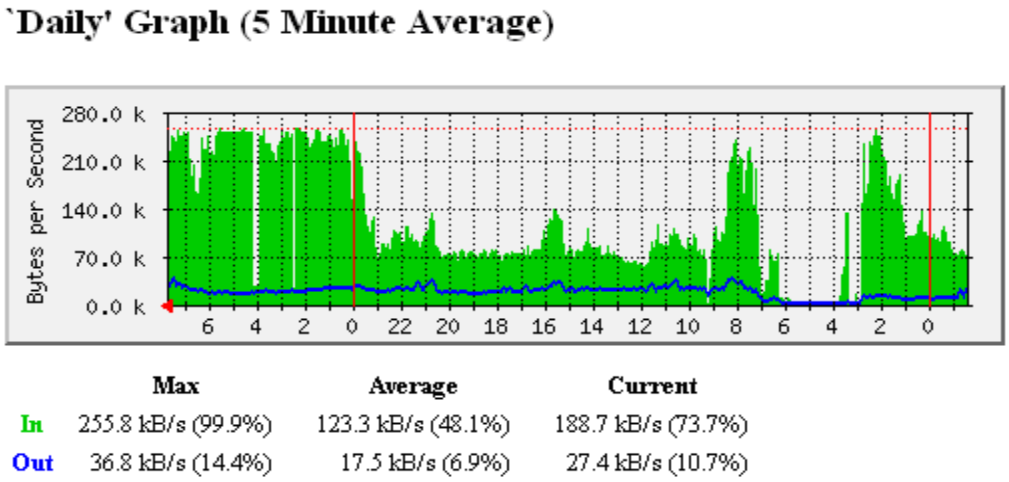


Figure 6: Traffic analysis using MRTG at 24 March 2010

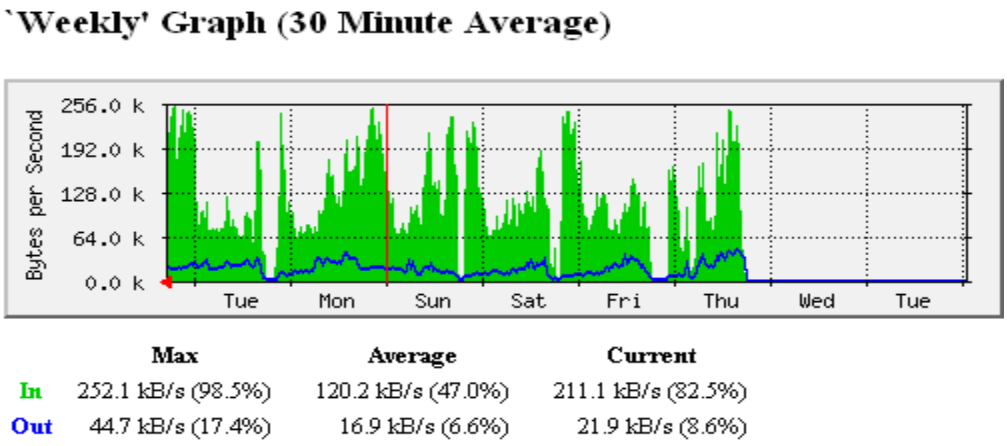


Figure 7: Traffic analysis using MRTG at 24 March 2010

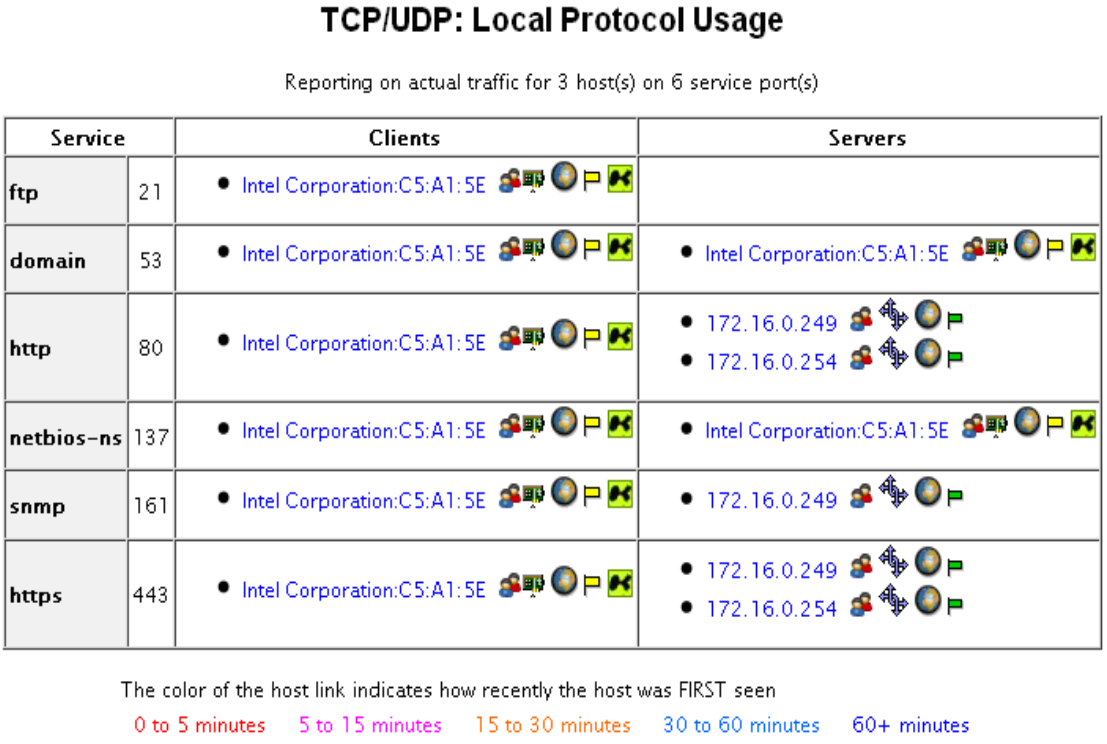


Figure 8: Local Protocol Usage

Active TCP/UDP Sessions

Client	Server	Data Sent	Data Rcvd
Intel Corporation:C5:A1:5E :36065	173-17-112-190.client.mchsi.com :https	23.8 KBytes	14.9 KBytes
Intel Corporation:C5:A1:5E :60147	d.yimg.com :http	1.0 KBytes	80
Intel Corporation:C5:A1:5E :36772	httpcs104p2.msg.ac4.yahoo.com :http	1.1 KBytes	160
Intel Corporation:C5:A1:5E :38144	us.mg2.mail.yahoo.com :http	1.3 KBytes	80
172.16.3.229 :61925	Intel Corporation:C5:A1:5E :squid	23.4 KBytes	0
Intel Corporation:C5:A1:5E :60842	d.yimg.com :http	3.1 KBytes	82.1 KBytes
172.16.3.35 :62568	Intel Corporation:C5:A1:5E :squid	1.8 KBytes	0
172.16.3.35 :62590	Intel Corporation:C5:A1:5E :squid	1006	0
172.16.3.35 :62628	Intel Corporation:C5:A1:5E :squid	754	0
172.16.3.35 :62632	Intel Corporation:C5:A1:5E :squid	639	0
172.16.3.35 :62636	Intel Corporation:C5:A1:5E :squid	639	0
172.16.3.35 :62655	Intel Corporation:C5:A1:5E :squid	634	0
172.16.3.35 :62661	Intel Corporation:C5:A1:5E :squid	519	0
172.16.3.35 :62663	Intel Corporation:C5:A1:5E :squid	519	0
172.16.3.35 :62681	Intel Corporation:C5:A1:5E :squid	372	0

Figure 9: Active TCP / UDP sessions

Network Throughput: All Hosts - Data Sent+Received

Hosts: All

Data: All

Host	Location	Data			Packets		
		Current	Avg	Peak	Current	Avg	Peak
Intel Corporation:C5:A1:5E		2.4 Mbit/s	1.0 Mbit/s	25.1 Mbit/s	836.8 Pkt/s	273.6 Pkt/s	2785.2 Pkt/s
a248.e.akamai.net		127.7 Kbit/s	2.0 Kbit/s	1.1 Mbit/s	21.9 Pkt/s	0.3 Pkt/s	133.1 Pkt/s
d.yimg.com		70.4 Kbit/s	1.9 Kbit/s	208.7 Kbit/s	17.1 Pkt/s	0.4 Pkt/s	50.0 Pkt/s
172.16.3.5		58.7 Kbit/s	7.2 Kbit/s	514.2 Kbit/s	45.1 Pkt/s	4.5 Pkt/s	245.0 Pkt/s
mail.yimg.com		55.9 Kbit/s	1.4 Kbit/s	771.0 Kbit/s	13.0 Pkt/s	0.3 Pkt/s	102.8 Pkt/s
us.i1.yimg.com		39.8 Kbit/s	371.9 bit/s	170.4 Kbit/s	8.0 Pkt/s	0.1 Pkt/s	31.8 Pkt/s
172.16.2.158		37.3 Kbit/s	421.0 bit/s	124.6 Kbit/s	11.1 Pkt/s	0.1 Pkt/s	37.3 Pkt/s
ads.yimg.com		37.3 Kbit/s	594.0 bit/s	114.3 Kbit/s	10.8 Pkt/s	0.1 Pkt/s	33.8 Pkt/s
west.thomson.com		30.8 Kbit/s	8.4 bit/s	30.8 Kbit/s	6.6 Pkt/s	0.0 Pkt/s	6.6 Pkt/s
attach.mail.vip.ukl.yahoo.com		29.1 Kbit/s	90.3 bit/s	65.5 Kbit/s	8.5 Pkt/s	0.0 Pkt/s	12.6 Pkt/s
www.yahoo.com		26.8 Kbit/s	244.1 bit/s	68.7 Kbit/s	4.9 Pkt/s	0.1 Pkt/s	12.0 Pkt/s
safebrowsing-cache.google.com		24.4 Kbit/s	10.8 bit/s	26.7 Kbit/s	4.6 Pkt/s	0.0 Pkt/s	5.1 Pkt/s

Figure 11: Network Throughput

ICT Driven E-Governance Public Service Delivery Mechanism in Rural Areas: A Case of Rural Digital Services (Nemmadi) Project in Karnataka, India

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Abstract

Information and Communication Technologies (ICTs) are playing a vital role in day-to-day public services. In the realm of machinery of Government, the ICTs application areas are promising to enhance the service delivery and improve the process and management of Governmental functionaries. This paper traces the current round of discussions on the appropriate roles and scales of Government with respect to ICTs driven e-governance application for enhancing service delivery in rural areas.

The paper reviews the efficacy of the policy framework in context of service providers and enhancement in delivery of goods and services to the rural society. The main issues related to service delivery are the role and multiplicity of organization, the coverage of services, and actual deliveries of goods and services. This is largely dictated by the preparedness of the service provider and as well as the extent of innovative technology used.

Karnataka is one of the pioneering States in India with respect to adopting innovative information technologies. The author has chosen to review on ICT driven e-governance Rural Digital Services (Nemmadi) project in Karnataka. It works at taluk level, covering about 38 citizen-centric services to the rural citizens. The vision of Rural Digital Services (Nemmadi) project is to empower the rural citizens, provide direct access of government services to the citizens and bring government services to the doorstep of the citizens thereby bridging the digital divide in Karnataka.

Key Words: E-governance, Public Service Delivery, Machinery of Government, Rural Digital Services, Citizen-Centric Service

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1. INTRODUCTION

Information Technology (IT) is emerging as a major instrument for shepherd in administrative reforms. The information technology that have changed ways of public services delivery system and promising efficient and enhanced service delivery to citizens. The current trend in Information and Communication

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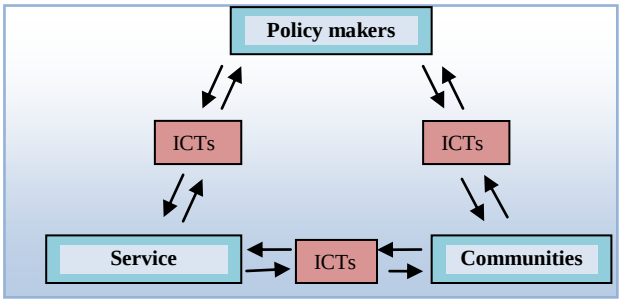
Technology (ICT) has brought a phenomenon which can be termed a "fourth revolution" in information technology. The first revolution comprised of films, radio, television and satellite broadcasting, while the second comprised telecommunications and microcomputers [Paisley, 1985]*. The third revolution what is called as Information Technology was said to promise not only a more productive person, a problem-solver and a lifelong learner, but also a better informed, rational and participative citizen, a modern 'renaissance' person, living in the web and network of a worldwide electronic community [Papagiannis et al, 1987] †. At present we have "fourth revolution" called as applications of Information and Communication Technology. ICT presents many avenues for improving governance. It has opened up new opportunities for governments to manage things differently and in a more efficient manner by utilizing information effectively and re-engineering processes. ICT tools are emerging as important instruments towards the goal of "good governance".

2. ROLE OF SERVICE DELIVERY PROVIDER

In India, according to 2001 census about 72 percent of population living in rural areas and majority of them are poor without access to basic services such as potable drinking water, sanitation, basic health care services, access to primary education etc. There are no institutionalised standards for the delivery of public services. Therefore, there always appears to be an unending struggle between the governmental systems, its capability to deliver and the actual needs of the citizens. For several decades public services have unfortunately been provided with the primary focus on convenience of service providers rather than on service receivers. Various factors like complex regulations, complicated forms, lack of information, absence of performance standards, lack of accountability, corruption and incompetence have left recipients of public services, or ordinary citizens, helpless, dissatisfied and frustrated. In many cases, the lack of implementation and absorptive capacity of government agencies and citizens respectively are problems that hamper efficient service delivery.

The delivery of services requires strong relationships of accountability between the actors in the service delivery chain. The main actors involved in service delivery sequence are central policy makers, state policy makers, service provider and general public. There is a need for accountability between Central and Local Policy makers and service providers. As depicted in Figure 1, new information and communication technologies (ICTs)‡, and e-governance applications can provide essential tools and mechanisms for poor communities to hold both policy makers and service providers accountable for a sustained supply of services. Therefore, e-governance would be mechanism for enabling transactions of governments which aid in governing a state or a community.



* W. Paisley, **Children, new media and microcomputers: continuities of research.** *Children and microcomputers: Research on the Newest Medium, 1985.*

† Papagiannis, G.J., Douglas, C., Williamson, N. and Le Mon, R., **Information technology and education-Implications for theory, research and practice.** IDRC, Canada, 1987.

‡ UNDP, **Pro-Poor Public Service Delivery with ICTs Making local e-governance work towards achieving the Millennium Development Goals,** APDIP e-Note 11 / 2007

Figure 1: Enhancing accountability, transparency and efficiency with e-governance

The ongoing challenge for government is that there are more people to serve, more services to provide, and greater investment is needed in "government preparedness." At the same time, most government organizations are being asked "to do more with less," and that places even more pressure on them to creatively and effectively leverage available technologies. The National e-Governance plan envisages the setting up of a state data centers (SDC) across the country and share infrastructure, allowing departments to access information easily and also cut costs in the process. The key interests of the main stakeholders are:

- **Government** - ensure the delivery of government services in effective and efficient manner;
- **Private partner** - growth opportunities through expansion of the domain and profitability; and
- **Citizens** - quality delivery of public service.

3. MACHINERY OF GOVERNMENT IN INDIA

The new Oxford English Dictionary defined as **'**Government is the sum total of the systems by which a state or community is governed'. The machinery of government in India comprising of three tier system; Union Government work at country level, State Governments work at State level and Local Self-Governments work at local level. Further local self governments are divided into Urban Local Bodies and Rural Local Bodies. When comes to Rural Local Bodies, the Karnataka Panchayat Raj Act, 1993 provided for a three-tier structure of local government with the Zilla Panchayat (ZP) at the district level, Taluk Panchayat (TP) at the middle level and Grama Panchayat (GP) at the grassroots level. The Zilla Panchayat (ZP) stands at the apex of Panchayat Raj System; the Taluk Panchayat is the middle tier and the Gram Panchayat, the lowest tier. The state of Karnataka was one of the very few states which took important steps to usher in decentralised governance, much before Panchayat Raj as a form of decentralised governance was acknowledged and institutionalised through constitutional amendments.

4. A CASE OF RURAL DIGITAL SERVICES (NEMMADI)[*] PROJECT IN KARNATAKA

Karnataka had a population of about 52.73 millions according to 2001 census, out of which about 66 percent of State population live in rural areas, about 56,682 rural habitats including 27,683 revenue villages. At present, there are 30 Zilla Panchayats, 176 Taluk Panchayats and 5,653 Grama Panchayats in the State. Karnataka State was at the forefront of India's ICT revolution and its capital, Bangalore, was the centre of the country's ICT industry. It is the home of new IT legends like Infosys Technologies and Wipro. Software exports from the state have been growing in dollar terms in the last ten years. A large number of IT startups have come up, and the state has been written about in business magazines around the world.

The Government of Karnataka was introduced 'one-stop -shop' Citizen Service Centres, which allowed members of the public to use a range of services electronically. *The Rural Digital Services (Nemmadi)* initiated in 2007, were originally intended to use Information and Communication Technology (ICT) to simplify procedures, ensuring transparency and improving the quality of the government's relationship with citizens as well improving overall citizen satisfaction. The Karnataka Government was justifiably proud of its United Nations award winning land registration and records system, *Bhoomi*[†]. All levels of the revenue department from the village accountant to the Deputy Commissioners (District Collectors) had been exposed to a very successful implementation of an e-governance program. Because of the bhoomi program, the computing infrastructure for deployment of an e-governance program like servers and connectivity to a central database was available at the taluka office of the revenue department. *The RDS (Nemmadi)*, through a network of 800 telecenters at the *Hobli* (group of villages) level, is an IT

[*] Meaning ***'hassle free'*** in the local language Kannada

[†] The *Bhoomi* (meaning 'land') project of online delivery of land records in Karnataka

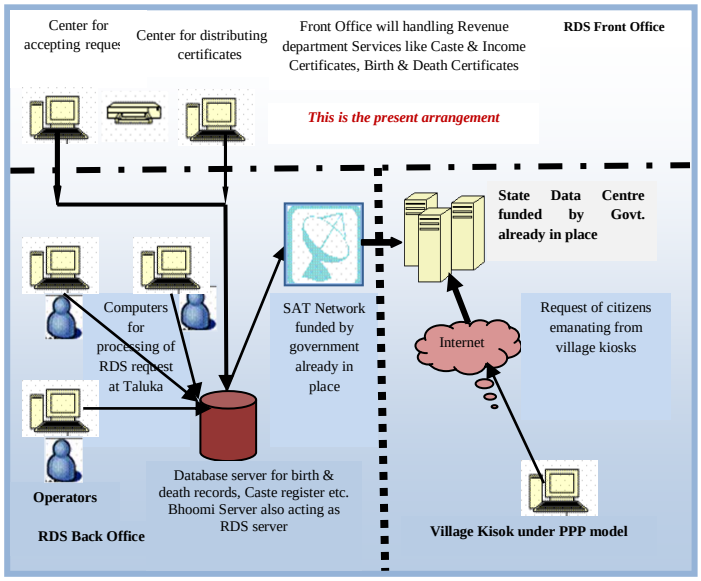
enabled rural initiative to deliver Government services at the citizen's doorstep. Through *Nemmadi* rural citizens can avail of Rural Digital Services (certificates issued by the Revenue department) as well as other services*.

5. BUSINESS MODEL

The RDS (Nemmadi) project was bagged by a consortium of IT firms – M/s Comat Technologies, 3i InfoTech, and n-Logue technologies. The initiative involves the deployment of 800 telecenters to supplement the 177 existing land record service (Bhoomi) kiosks that operate sustainably at the sub district level. The state government owns the project. As part of the build-operate-transfer (BOT) model, M/s Comat build, deploys, and maintains the kiosks for an initial five years. M/s Comat and its partners expect to recover their investment in equipment, infrastructure, and human resources within that five-year period. Services delivered through the RDS, comprising more than 38 government processes, include copies of land records, approval of old age pension for senior citizens, issue of caste certificates, issue of income certificates, birth & death certificates, land holding certificates etc. A fixed transaction charge of Rs. 15 is levied for each service and the private partner is paid a part of the transaction charges.

6. COMPONENTS OF RDS (NEMMADI) PROJECT

The RDS comprises of the following components: a) State Data Centre- Karnataka has been one of the first states to create a State Data Centre for both hosting all e-governance applications of the state and acting as a disaster recovery centre. The State data center is service delivery channels to departmental servers were directly connected to the internet; b) Wide Area Network- The current delivery of RDS services, the State government has set up a network of VSATs linking each of taluka servers to the State Data Center; and c) Delivery Channels - Taluk servers are both local repository of data and additionally data updation. Village Telecenters are another channel for the citizen to make requests and access. In most cases these Village telecenters comprises of one or two computers with associated peripheral devices such as printers, scanners, web cameras and they connect to the internet through various dialup technologies.



* Electricity bill collection and other services such as education through *Sarva Shiksha Abhiyaan*, collection of panchayat taxes, data entry for various departments and data updation of hand held devices.

Figure 2: Diagrams of RDS components in Revenue department Source: Reproduction from RDS (Nemmadi), Government of Karnataka

The various components of RDS (*Nemmadi)* are shown in Figure 2. The village level telecenters are the channels of delivery of various G2C services to rural citizens. The requests received at the kiosks are processed at the taluka back offices, which is connected to the government offices. *Nemmadi* and *Bhoomi* projects use the same database at the taluka levels, which is updated constantly. The consolidated database of land records of the entire state is maintained at the State Data Center (SDC). Requests for the *Nemmadi* services are transferred to the taluka servers through the SDC. Subsequent to receiving the electronic request from the Telecenters through the SDC, the request is processed by appropriate authority (*Tehsildar)*[*] for verification and validation. On receiving the comments of such appropriate authority, the final certificate is generated and is digitally signed by the competent signatory, which is then downloaded at the village telecenter and issued to the applicant see Figure 3.

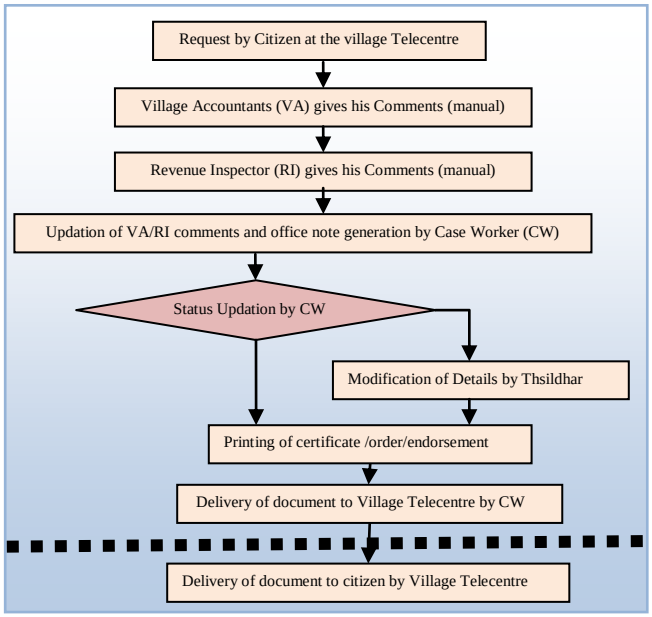


Figure 3: a typical workflow process for delivery of service at taluka that was computerized through the Rural Digital Services

7. SOFTWARE FOR RDS SERVICES

The software for delivery of RDS services was developed on the Microsoft Platform and uses MS SQL Server. It has several innovative features like multiple modes of delivery of services. Some of the software features are given below:

- Reports - Use of RDS software allows one to track the delivery of certificates and also to monitor and thereafter rectify the delays in processing of the citizen service requests.

[*] A tehsildar is revenue administrative officer in Pakistan and India in-charge of obtaining taxation from a tehsil, meaning tax collector. (http://en.wikipedia.org/wiki/Tehsildar) (Accessed on 7th July, 2009).

- Offline functionality - The RDS software has been built on a rich client model with the master data being stored in the local machine also. This allows the application to deliver both online and offline functionality, i.e. service requests of the citizens at the village telecentre can be saved in the local telecentre machine even when connectivity to the SDC is not available. The advantage of this functionality is that citizen can make the service request even when internet connectivity is not available.
- Use of digital signature - The RDS software has a feature of digital signature by the issuing authority. The RDS software generates an XML of this digitally signed certificate and displays it as a 2 D bar code. This feature can help both in checking the authenticity of the certificate and can be later used to dispense with the physical signature of the official on the certificate.
- Smart update facility - Since the RDS client is a rich client application, there is a need for constant updates for incorporating new functionalities. However, since the village telecentres will be located in remote places, the smart update facility will help in maintaining uniformity of the software application across all delivery points.
- Biometric authentication - Finger print authentication for login and updation is used for non-repudiation by the government officials.
- Unicode - Unicode is being used to store data in the local language. The software can be customized to allow multi-language user interfaces. Currently Kannada and English languages are supported.

8. PERFORMANCE EVALUATION OF RDS (NEMMADI) PROJECT*

The performance evaluation analysis was done by Indian Institute of Management, Bangalore during June-July, 2008. The study covered 300 service users from 4 villages were selected in two districts of Karnataka viz., Ramanagara and Chamarajanagara were interviewed. The citizen survey and opinion about efficiency of service delivery data reveals that that service provisioning through these centers have significantly reduced the time taken to obtain RTC, Land holding certificates etc. The level of citizens' satisfaction of various attributes of services at RDS (*Nemmadi)* centers, data reveals that citizens are highly satisfied with the new delivery process, speed and responsiveness of staff, while accuracy of services and records as well as facilities at the centers were satisfactory in both the districts. Whereas in the pre - RDS (Nemmadi) days, where citizens had to wait for the visit of village accountant to initiate the process of obtaining certificate.

The RDS (Nemmadi) project bags the National Award for e-governance - Silver Award for 2007 - 2008, Microsoft e-governance leadership Award for 2007 and Government Technology Award for e-governance, 2007

9. CONCLUSION

In the wake of increasing challenges to deliver quality of public services in developing counties like India, ICT driven e-governance applications making the citizens happier with timely and cost savings in availing services and improvement in the reliability of services. Special emphasis is needed in working out revenue models, ensuring the full implementations through appropriate tenure appointments of project champions, ensuring effective monitoring and maintenance of systems. It is important to understand the 'whys', 'which' and the 'how's' of public service delivery. It is very difficult to define this term. We do not have any comprehensive definition or understanding of what really is public service delivery. Briefly put, it is the inter-relationship between the government functionaries and the citizens to whom the services of the government are addressed to, and the manner in which the services reach those for whom they were intended. Any effective public service delivery mechanism must ultimately lead to good governance. The

* Gopal Naik, K .P. Basavarajappa, Nageena Sultana and Prasanna Rashmi K K, **Public Value Creation through Private Partnership: Lessons from Public Service Delivery in Karnataka,** IIMB, June- July, 2008.

governments generally utilise one or the other of a variety of mechanisms for delivering services to the citizens. There is no limit to the scale of such composite applications. Once the structure is in place, governments can more easily get down to the business of public services.

The RDS (Nemmadi) project is different from most models that currently exists is that its services are based on volume rather than the high-up front costs that other models have difficulties supporting. For example, 20 million land records divided by 176 taluk offices results in 113, 636 records per back office. Priced at Rs. 15 (US$0.32) per RTC certificate, this average to Rs. 1, 704, 545 (US$ 36, 823) per office revenue per year. This is sufficient to cover operating costs, provide a modest return to State revenues, ensure good service levels and result in profit making proposition for private investors such as M/s Comat Technologies and its partners. For other services, such as issues of birth and death certificates, Caste certificate etc. yields supplementary revenue to the Service provider. A key challenge for public service delivery is in designing and implementing a system that holds service providers accountable for the services delivered. Even if the clients are able to reach the policy makers, this does not necessarily lead to improved services because the policy makers cannot ensure that the public service provider (whether public, private or civil society) will deliver the services due to an equally long route of accountability between the policy makers and the service providers[*].

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The CHARMS Application Suite: A Community-based Mobile Data Collection and Alerting Environment for HIV/AIDS Orphan and Vulnerable Children in Zambia

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Abstract:

World Vision (WV) uses the Core HIV and AIDS Response Monitoring System (CHARMS) to track and measure core indicators related to individuals with HIV and AIDS within the communities WV serves. WV uses community care coalitions of volunteer caregivers to care for orphans and vulnerable children (OVC). Current CHARMS data collection involves the registration of caregivers, households and OVC. Data is manually collected by caregivers about OVC during monthly home visits and manually aggregated semi-annually. This research project developed a software application that runs on a low-cost cell phone to automate the CHARMS data collection, alerting and reporting process. The mobile application allows for caregivers to record CHARMS data using the mobile application and transmit the data in real-time using an SMS-based wireless communication service. The application also includes real-time web and email based reporting and mobile phone alerting based on key events (food shortage, OVC not visited). During the summer of 2009, a field pilot project was conducted in Zambia involving 10 caregivers. The system allowed for the registration of 300 OVC and 200 households. A total of 145 home visits were recorded via the mobile application. Extensive assessment data was collected during the field experience. 100% of the caregivers would recommend the continued use of cell phone to record CHARMS data for reasons ranging from time savings (90%), ease of use (70%) and more interesting to use (40%). The caregivers said the cell phone application either had a very positive (80%) or positive (20%) impact on the quality of their home visit.

Keywords: mobile field data collection, SMS, OVC, HIV/AIDS_

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1. INTRODUCTION

In 2006, World Vision (WV) [2010] introduced CHARMS (**C**ore **H**IV and **A**IDS **R**esponse **M**onitoring **S**ystem) to track and measure core indicators related to HIV/AIDS within the communities they serve. WV uses community care coalitions of volunteer caregivers (herein referred to as caregivers) to care for orphans and vulnerable children (OVC). Current CHARMS data collection involves the manual registration of caregivers, households and OVC. Data is manually collected by caregivers during monthly home visits and manually aggregated semi-annually.

A high-level business process model for the existing CHARMS process follows. It depicts the role of Community Care Coalitions (CCCs) as community-based partners for World Vision and other NGOs to coordinate the HIV/AIDS response effort. World Vision field operations are managed via a hierarchical structure. The world is divided into regions spanning multiple countries. Each country where World Vision is involved is managed via a National Office. The programs within a country National Office are broken down into Area Development Programmes (ADP). ADPs contain community care coalitions (CCC). Caregivers are volunteers that work in conjunction with a CCC. OVC are managed are part of an ADP.

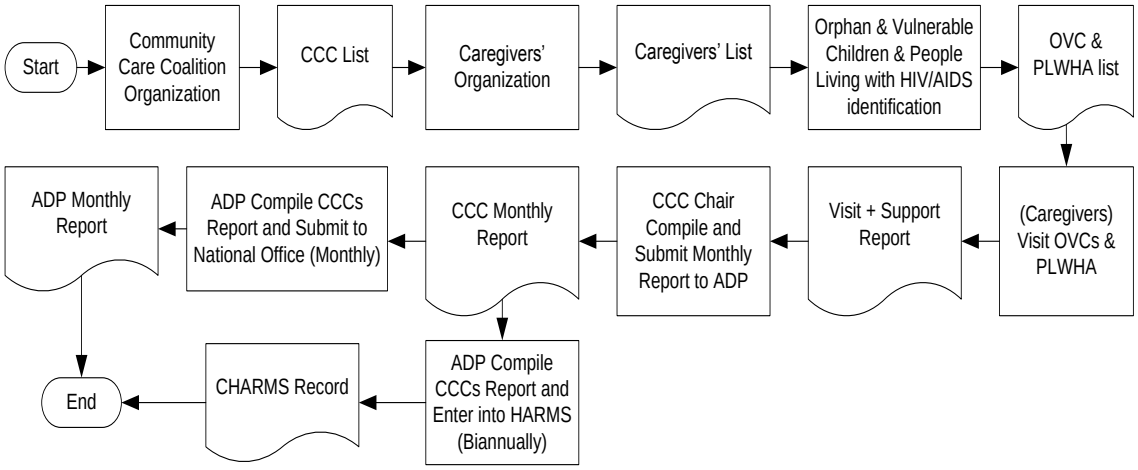

Figure 1. CHARMS current process model

The overall purpose of the pilot project was to transform the current manual CHARMS data collection and reporting process into one that was mobile-based and real-time. The project had the following goals:

- To train WV field staff and volunteer caregivers (CGs) on the use of mobile and web applications and to see them successfully use the applications;
- To test the usability of the mobile and web applications by WV field staff and caregivers;
- To explore and understand the connectivity options (cost, reliability, security, etc.) for transmitting the data from the mobile device to the database;
- To develop a cost/benefit analysis to validate the mobile concept;
- To validate that the data has been correctly entered and correctly stored in the database;
- To explore reports that would be helpful to WV staff related to CHARMS forms;
- To define new features to explore for making the applications more valuable to WV;
- To record lessons learned about the project.

The initial prototype for this project was developed as part of two service-learning courses taught at Messiah College over a twelve-week semester during the spring of 2009. The two courses were a database applications course and a systems analysis and design course. Service-learning is a pedagogical model in which student learning is greatly enhanced through practical, experiential projects. For a course at Messiah College to be considered as service-learning course, it must contain the components of:

- Service: students must engage in meaningful service that is mutually beneficial. In this case, the development of the mobile and web applications for World Vision to be used in Zambia was the service component of the courses. As part of our understanding of service, the professor and students saw the project as inspired, guided and directed by James 1:27 "Religion that God our Father accepts as pure and faultless is this: to look after orphans and widows in their distress and to keep oneself from being polluted by the world."
- Content: students must be exposed to the non-profit organization and people group which they are serving so that they may better understand the motivations or the organization and needs of the people they are serving. In this case, World Vision staff lectured in classes at Messiah College and the students were able to interact with field personnel about the nature of their work and those they serve. In addition, World Vision staff showed various videos of their staff interacting with the OVCs.
- Reflection: students must reflect on their experience in terms of how it informs their notions of vocation and calling in life. In this case, students maintained journals and were prompted throughout the semester by the professor with probing questions that acted as a catalyst for journal entries. At the conclusion of the semester, students submitted a paper that chronicled the nature of their reflections over the semester and summarized the main ways in which this experience informed their notions of vocation.

In addition, several of the students from these classes and the professor worked over the summer of 2009 to complete the project and ready it for field usage. Field trials of the prototype occurred during the latter part of the summer of 2009.

2. CHARMS APPLICATION SUITE

2.1 Introduction

World Vision has a keen interest in the use of mobile technology to facilitate field data collection and rapid response systems. The convergence and ubiquitous nature of mobile devices and communications technology has created an unprecedented opportunity to reliably, securely and economically connect remote end points to central repositories of data. World Vision desired to pursue a *"proof of concept"* prototype project to explore the efficacy and appropriateness of deploying mobile applications in the developing world.

This research project developed a software application, using the JavaRosa [2010] open source platform that runs on a low-cost cell phone to automate the CHARMS data collection, alerting and reporting process. The mobile application allows for caregivers to record CHARMS data using the mobile application and transmit the data in real-time using an SMS-based wireless communication service on a low-cost Nokia phone. The application also includes real-time web and email based reporting and mobile phone alerting based on key events (food shortage, OVC not visited).

There are two different categories of system users. The first category of user is the mobile user. This is likely to be a caregiver or World Vision field staff. The second category of user is the web user. This is a user who actively uses the web application to enter agency, household, caregiver or OVC-related data. This might include a World Vision field manager, a CHARMS manager, World Vision National Office staff or a World Vision IT manager.

2.2 Future State CHARMS Process Model

The major improvement of the CHARMS business process focuses not in eliminating the main business processes, but on the way data is collected, transmitted, stored, analyzed and reported on. Instead of the caregivers submitting their activity reports to the CCC chairman, they will directly send the data to a central database via the mobile application.

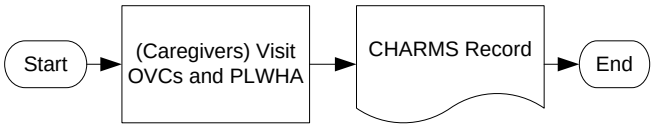

Figure 2. CHARMS future state process model

Once the data is stored in the CHARMS database, it can be accessed on-demand through a web application containing pre-defined reports. Unlike the existing CHARMS process where data is complied twice (at the CCC level and at the area development programme [ADP] level), data is only captured once in the new CHARMS process. Secondly, the compilation and aggregation of the data is automatically done in the new CHARMS process versus the current CHARMS process where data is manually aggregated. Finally, in the new CHARMS process, detailed individual home visit data can be easily obtained as there is full traceability from the aggregate reports to the individual records versus the old CHARMS process where data is not automatically traceable once it is aggregated. Though this information is not relevant for high level data consumers (e.g. for experts at the National, Regional or Global level), the existence of data in that traceable detailed form helps to perform root cause analysis which is difficult to do in the existing CHARMS process.

2.3 CHARMS Application Suite Architecture

Figure 3 shows the high-level architecture of the CHARMS application suite.

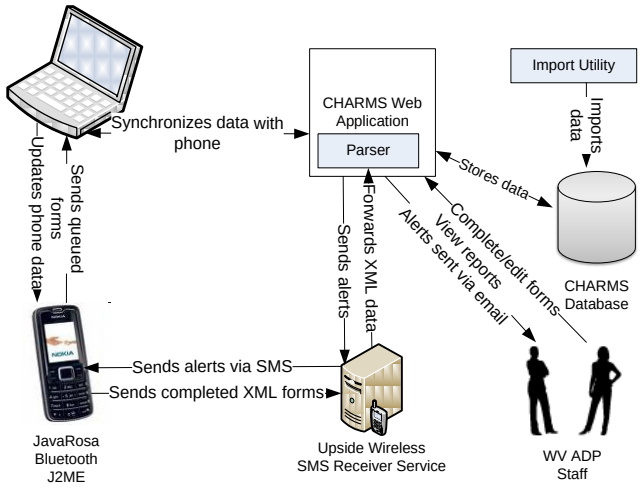

Figure 3. CHARMS high-level architecture

The CHARMS mobile application runs on the Nokia 3110c low-cost cell phone. The phone provides the J2ME platform [2005], which runs the CHARMS application. This mobile application is a customized version of JavaRosa [2010], an open source data collection tool that runs on J2ME. The JavaRosa framework includes a form engine as the primary means for data collection. After one of these forms is completed on our custom JavaRosa application, the CHARMS data is encoded in XML and transmitted as a series of SMS messages from the mobile phone over the GSM network. This data is sent to the Upside Wireless SMS receiver service [2010]. In turn, the SMS receiver service forwards the SMS messages over HTTP to a custom web application. The web application contains a parsing engine that decodes the XML-

encoded form data and inserts the data into the MySQL CHARMS database. The CHARMS database allows for various CHARMS-related reports to be produced on-demand. The CHARMS database also monitors the data for various critical events identified (i.e., a child in need of food, etc.) and immediately transmits a message over SMS via the SMS receiver service to a mobile phone or email address to alert on a potential emergency. Finally, the desktop/laptop application is a Java program that is used to communicate with the mobile CHARMS application software and database over the Internet. It allows for software and client list updates to be made to each of the mobile phones and for data on the mobile phone that could not be transmitted over SMS to be transmitted to the database over the Internet.

2.4 Mobile Application

The process of designing a mobile application that would collect information for the CHARMS dataset originated by identifying an open source project that was extensible and easily customizable. JavaRosa [2010] was chosen for our mobile component as it is an open source project designed for data collection, analysis, and reporting using a low cost cell phone. Although JavaRosa proved to be a great fit, our objectives required much modification and customization of this application to support the World Vision CHARMS business process.

After choosing the JavaRosa platform, a cell phone was required to run the mobile application. For our purposes, we required a low-cost cell phone as the primary users would be volunteer caregivers. One of our constraints of the project required keeping the price of cell phone hardware down to reduce the cost of procurement of tens of thousands of phones and potential replacements for theft or damage. In addition, we spoke with the JavaRosa support community for recommendations on compatible cell phones that were known to be quality builds to withstand the conditions of rural areas of Africa. This research pointed to the Nokia 3110c which was determined to be the phone that would run our customized JavaRosa application.

The CHARMS dataset required a custom menu structure to provide easy interaction to the caregivers. The main menu (Figure 4) of the application allows a caregiver to complete a form for a monthly visit, household registration, or OVC registration. Our menu design was driven by the relational aspects of the objects in the CHARMS framework. For example, in CHARMS, a household contains one or more children. Therefore, on the main menu, if the caregiver attempts to perform a standard home visit with an OVC, the caregiver must first select the household they are visiting. Once the household is selected, a list of OVCs that reside within the selected household is shown (Figure 5). Note that in Figure 5, the names of blackened out to not disclose the names of actual OVC. This menu structure not only increases the efficiency of the caregiver, but also eliminates the chance of misspelling a name and helps us better track each OVC in the CHARMS database.

Figure 4. Mobile application main menu

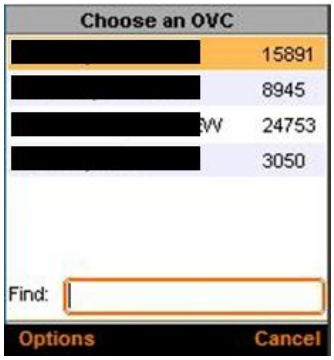

Figure 5. Mobile application selection of OVC

The JavaRosa project includes a module that allows for quick creation and deployment of question and answer forms by utilizing the industry standard XForms [2010]. Our team built forms to model the CHARMS dataset by creating simple questions using the various question types supported by XForms. Through these options, XForms allowed our team to focus our design to minimize the amount of typing required by the user to enter data into the system. Thus, we created more of an objective approach to CHARMS data collection. For example, the mobile forms were designed to utilize check boxes to allow for

easy recording of key indicators by simply selecting items needed by the OVC or support that was provided from a checklist (food security, social/psychological assistance, abuse/neglect, etc.). Another use of XForms was using conditional questions. For example, CHARMS data collects information about the OVC's parents. Information about if the child's mother and/or father are alive or ill. Using conditional questions, if the mother or father is dead, we will not ask if that parent is ill. XForms transparently takes the answer to a previous question and displays an appropriate next question. A key benefit of this design includes reduced costs for data transmission since only selection numbers from a list were transmitted instead of long input text strings. This design also minimized the amount of typing and time required to enter data, thereby reducing the opportunity for erroneous data entry by the caregivers.

2.5 Wireless communications

Once the form has been completed, the JavaRosa application transparently creates an XML structure (from XForms) and sends the data via SMS. Depending on the number of characters in the XML encoded string, JavaRosa splits the XML string into a number of SMS messages in an organized way to deal with the issue of long form data (SMS messages are limited to be no more than 160 characters). Before the message is sent, the caregiver is presented two options based on the perceived emergency gained from the home visit.

The first option is "Send Now" which immediately sends the completed form via SMS. In order to keep data transmission costs low and anticipating that the phones may not have great cellular coverage in our target location, our team built the mobile application to save by default a completed form that was unable to be sent. As we indicate later in the paper, cellular coverage in our target location did not prove to be a problem. However, in the chance of limited or no connectivity, unsent forms would be placed in a queue and could be sent the next time the caregiver entered into a coverage area.

For the second option, if the results of the home visit did not appear to be an emergency, the caregiver could choose "Send Later", which would allow the completed form to be saved on the phone and sent to the CHARMS database at a later time.

A final piece to the mobile application was the need for an SMS receiver service. This service acted as an intermediary between the text messages and the database. Our team negotiated with Upside Wireless [2010], a large player in the SMS receiver service market, to handle receiving the text messages. The basic role of this service was to provide a phone number for the mobile application to send the SMS message. Upon receipt, the message would be forwarded over HTTP to our website, which parses out the data from the XML and stores it in the CHARMS database.

The SMS receiver service also provided the ability to send a message back to a specific cell phone. This feature was used to send various alert messages back to the caregivers based on specific events generated by the database.

2.6 Desktop/laptop application

The mobile application's SMS feature is an integral piece to successfully perform mobile data collection. However, while designing the application suite, our team realized in order for our solution to be scalable, a direct communication channel would need to be set up to the CHARMS database. We envisioned the need for OVC client lists to be pushed onto a cell phone issued to a caregiver if the phone was lost or stolen or if OVC data was updated via the web application. Further, we needed a solution that could drive cost down from solely relying on the GSM wireless network.

Using these requirements, our team determined that an application on an internet-connected computer would solve these issues. However, a connection between the computer application and the phone would need to be established. Bluetooth became the technology of choice to synchronize the phones with the computer application.

Bluetooth was chosen for a variety of reasons. First, programming libraries and large support communities exist for the standard (compared to proprietary cell phone USB connection cables). Second, Bluetooth was not limited to a specific phone manufacturer and USB connection cable. Rather, the standard can be utilized by any phone that offers Bluetooth capabilities. This was an important consideration as future versions of the mobile application might need to be run on a variety of cell phone makes and models.

Therefore, the choice of Bluetooth for data transfer between mobile phone and desktop computer proved to be favorable.

With this design decision, we created the mobile application to perform an initial configuration step that mapped the cell phone number to a caregiver. This operation allows the computer application to download the caregiver's entire client list of OVCs and households from the CHARMS database and sends this information to the phone via Bluetooth. Upon completion of this step, the caregiver could begin using the phone for data collection.

The second purpose of the computer Bluetooth application allows any unsent messages or unsynchronized data to be sent to the database from the phone via the computer application. The queued messages could be a completed form for OVC registration, household registration, or a home visit that was not thought to be an emergency and the caregiver chose "Send Later".

One issue we ran into was the case where a caregiver might register a child and would want to complete a home visit form during that visit. However, when the child is added on the phone, it does not have a unique key generated by the database. Thus, our team created a method to temporarily assign keys for that child, so the caregiver could perform their home visit. Upon synchronization to the database, these temporary keys would be converted to the database generated keys resulting in the synchronization of the CHARMS database and the phone data. In addition, during a synchronization using the computer application, any new or updated households or OVCs created from the web application would be added to the mobile application.

By incorporating the Bluetooth application on a computer connected to the internet, we are able to have much more flexibility in future designs. Additionally, through the benefits of cost savings and updated client lists, we could better manage the data between the cell phone application and the central CHARMS database.

2.7 Web application and database

A complimentary web application was designed for quality assurance and viewing data by ADP staff. The web application is not a vital piece for field data collection; however, it serves as a management window to view the status of an ADP.

The web application utilizes user management with various rights depending on the needs of the user. For example, an ADP manager might have the ability to create users within their specific ADP, but not in others. Thus, the web application serves as an interface for the ADP staff to help monitor the programme they are managing and review recent updates sent by the mobile phones and perform corrections and updates as needed. While not all data would be reviewed, an intuitive interface is available in the case of any needed changes.

The web application also provides the ability to enter in new data. Each of the forms available on the mobile application is available for the web application user. The web application does have additional forms for management of the ADP. For example, a form to add a CCC was created and an "OVC – caregiver assignment" form is available. The latter form allows an ADP staff web user to change an OVC to a different caregiver if such a circumstance were to come up.

Additionally, the web application provides the programmatic interface between the SMS receiver service and the database. The web application includes a robust parsing engine that takes the raw XML messages sent by the mobile phones, reconstructs, decodes, and stores the data in the CHARMS database. The database backend is created in such a way as to keep data organized and allows for easy reporting. This concept provides great flexibility in not only reporting but also in alerting (discussed later).

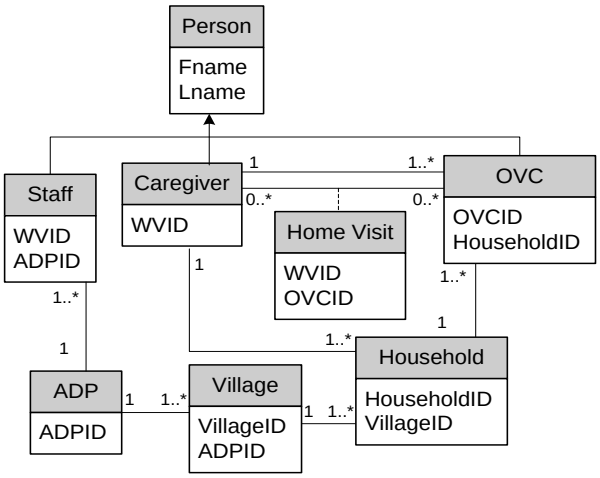

Figure 6. High-level database model

The CHARMS dataset, collected manually, includes redundancy within the data that was collected to keep the information organized. However, by storing the information in a database, our team was able to use an entity relationship model to abstract out super-types and sub-types to avoid redundancy and keep the information storage more structured and organized. For example, a super-type in our database model was the person class. This class contained three sub-types of WV staff, caregivers, and OVCs (shown in Figure 6). Similar to the structure used on the mobile application, the database allows one or more OVC to be contained in a household unit and a caregiver to care for one or more OVC. Additionally, the CHARMS dataset hierarchy included groupings by location and by caregiver allowing relationships to exist, which could be leveraged by reports.

2.8 Reports

The web application not only provides the ability for an ADP manager to monitor, edit, and enter new data, but one of the more powerful features is the reporting engine. Our team found reports to be easily designed and implemented due to the granularity of the data captured at the database level. These reports provide many new options to World Vision staff compared to the old aggregated data reports created from the manual method.

The old process of generating reports for stakeholders of World Vision includes a tedious process of manual data entry and aggregated data to produce a high level report. ADP managers and other ADP staff would spend several days aggregating data provided by caregivers from handwritten notebooks. Human error has become an issue in aggregating numbers and misreading entries written by the caregivers. Therefore, the accuracy of data from this manual collection method presents an issue to World Vision, as the reports help decide the amount to invest into the communities.

Additionally, this manual system burdens the larger national directors as they are required to take time to sign off on the data and declare the data valid. Following this action by national directors, a final head of CHARMS would need to prepare final reports to the World Vision stakeholders. By implementing the reporting aspect to the web application, this time consuming process is essentially removed.

Utilizing the structured relationships and near real-time data, the reporting engine leverages the database to provide highly accurate and extremely detailed reports. The central storage provides a streamlined approach to reducing the excess hours to complete and aggregate reports. In fact, the reporting section of the web application provides reports similar to the old reports produced as well as other varieties.

A few reports we created include a CCC report, annual report, ADP report, indicator report as well as others. The CCC report displays each caregiver, the households and the OVC for which they tend. The annual report is similar to the aggregated report used by World Vision with additional options. The ADP report lists all the CCCs in that ADP and the number of caregivers, households, and OVC in a specific

CCC. The indicator report can show percentages for each indicator (food, health, etc.) for a CCC, ADP, or nationally.

These new reports allow managers to drill down into more details if desired. For example, whereas previously reports were rather high level in nature, reports can now look at communities, ADPs, regions, or other levels as well. Due to the structured database, the types of reports can be rather dynamic and easily created to suit future needs for better allocation of funds and staff and other trending. For example, one report displays a caregiver and the number of households, OVCs, and visits that individual made during a specific time period. This report would allow an ADP manager to better identify areas of high volume to help reduce the burden on each volunteer caregiver.

2.9 Alerts

While database driven reporting helps greatly reduce World Vision staff's effort required to produce reports, alerts provide a means to benefit individual communities. Alerting was implemented in several areas. Each application allows for a better quality of service to communities aided by World Vision.

For example, our team set up a trigger that would alert an ADP if an OVC were under an extreme circumstance and needed immediate attention. One of the CHARMS indicators is the amount of food a child available to a child. In the pilot, if a child had not eaten for more than a day, we instructed the caregiver to mark the "Food" indicator and select the "Send Now" option to send the completed form. Once this form reached the database, a trigger was called and an email was sent to an ADP office where they could take immediate action and instruct staff where to deliver the available aid.

Alerting was also used for accountability reasons. For example, a caregiver is supposed to visit a child at least once a month. However, sometimes caregivers might lose track or neglect to visit a specific child. In such a case, a child might be ill and in dire need of attention. Therefore, the database periodically scans through each child's record and checks to see when the last visit was performed. If the child was not visited for a given length of time, such as 25 days, the database would use the SMS receiver service to forward an SMS message back to the caregiver's phone to remind them of which child needed to be visited and how much time elapsed since the last visit.

2.10 Data import/export

The features and solutions our application suite provides perform well as data is added to the database. However, initially, our team needed to add preexisting data into the database. For example, for the main menu to work as intended, we needed a list of the households and OVC each caregiver looked after.

We were able to obtain Excel spreadsheets of the current data for each caregiver in the pilot along with each OVC they cared for and the households they resided in. Our team wrote a custom script to import the data from the spreadsheets into the database.

While the data import tool proved to be successful, to be scalable, future consideration would be given for a more robust "Extract-Transformation-Load" (ETL) tool, such as the one Songini describes [2010]. Such a tool could import large amounts of data into the database from a variety of import formats. As a future consideration, it would be useful to allow data to be exported from the database in the form of well-formed Excel files as well.

3. PILOT PROJECT

A pilot project of the CHARMS application suit was conducted in Zambia during the summer of 2009. The pilot project involved the participation of various World Vision field staff and ten volunteer caregivers. A faculty member and senior student were involved in the Zambia fieldwork for approximately three weeks. The total pilot project was five weeks in duration. The ten caregivers who participated in the field experience were half male and female. Their education ranged greatly from: 30% primary school, 50% secondary school and 20% college. 80% of the caregivers indicated they used a cell phone to make a call prior to beginning this project. 60% of caregivers indicated they used a cell phone to send a text message prior to beginning this project.

3.1 Training

The pilot project began with a three day training session. The training materials (PowerPoint slides) were written and presented in English. The spoken words of the training were translated (in real-time) by one of the caregivers in the local language dialect. The training covered the following topics and audiences:

1. Phone training (primary audience: caregivers)
    a. How to use the phone
    b. Typing on the phone
    c. Creating, editing and submitting CHARMS forms on the phone
    d. Guidance on how to best use the mobile application

2. CHARMS application training (primary audience: World Vision ADP staff)
    a. Navigating the web application
    b. Creating, editing and submitting CHARMS forms via the web
    c. Guidance on how to best use the web application
    d. Web administration and IT manager training (primary audient: World Vision ADP staff and IT staff)
    e. Navigating the CHARMS application suite web site
    f. Logging into web application
    g. Administering users
    h. Forms
    i. Reports
    j. Alerts
    k. Problem Reports
    l. Installing the mobile application
    m. Desktop synchronization and updating the mobile application

The primary challenge of the training proved to be linking the manual approach to the mobile phone solution. Walking through each of the forms along with role-play activities proved to be effective. Additionally, pairing caregivers based on comfort level of the application allowed sharing of knowledge and understanding. A field ready reference guide developed in the native language would have been very beneficial.

3.2 Field Activity

Over the five-week pilot project period 247 OVC were registered via the import utility and 54 OVC were registered via the mobile application. 167 households were registered via the import utility. 32 households were registered via the mobile application. 142 home visits and 3 end home visits were recorded via the mobile application. All ten caregivers were actively involved in using the mobile application throughout the pilot project.

3.3 Field Assessment

Surveys given throughout the pilot revealed a positive attitude and experience with the mobile application. 100% of the caregivers believe the cell phone keeps information safer and more confidential than the paper method. 100% of the caregivers believe CHARMS forms can be completed quicker using the mobile application than writing down data in a notebook. 100% of the caregivers would recommend the continued use of cell phone to record CHARMS data for reasons ranging from time savings (90%), ease of use (70%) and more interesting to use (40%). The caregivers said the cell phone application either had a very positive (80%) or positive (20%) impact on the quality of their home visit.

For every home visit we observed, there were 1-2 communication bars on the phone (average of 2.07 bars per visit). However, when caregivers were surveyed, 3 (30%) of them indicated that they had difficulties sending data because they could not get a communications signal. It is not clear if the caregivers correctly understood the question, as our field work indicated that every one of the 15 household locations we visited had a communications signal.

We devised a data accuracy protocol, but the field staff was unable to complete it for personal reasons. However, the mobile application was designed to minimize typing by displaying more objective style questions. Therefore, we have a high degree of confidence that the information received by the cell phone application was complete and accurate. We have done some high-level spot checking of the data in the database for data accuracy based on our limited knowledge of the OVC and community caregivers. It appears as if data was accurately transmitted from the mobile phone into the database, although some number of typographical errors appears in the data.

In terms of process execution, there are two key metrics to focus on. Process duration (the amount of elapsed time required to complete a process) and process effort (the amount of work effort required to complete a process). During our field experience, we observed a negligible difference between the effort required between the manual approach and the mobile phone process for completing registration and home visits. From observation, the comparative effort required to produce reports using the manual process vs the automated process is dramatically different. With the automated system, producing reports is instantaneous vs significant effort and duration required to produce the reports with the manual process. In addition, the report generation process using the automated system drastically increased both precision and detail and cut the time to compile the reports significantly from the manual approach. Further, the reporting feature of the automated system allows for new reports of greater analysis and provides flexibility of reporting with the specific nature of the stored data. Process effort and duration have both been greatly reduced for producing reports using the automated system. All of the registration processes have duration of 2-4 weeks using the manual system; the registration processes have duration of 15-30 minutes using the mobile phone (given that registrations are instantly available). In short, process duration has been substantially reduced for reporting and getting data into the automated system.

One key aspect to the mobile system is the ability to send data in real time. During the pilot, an alert email was sent to WV staff if a caregiver selected a food shortage during a home visit. Properly implemented, this system could track other emergency issues to provide immediate response by WV staff. Similarly, an administrative email was sent to WV staff and an SMS message was sent to the caregiver if a child had not been visited within a given number of days to help develop accountability to the caregiver position.

We held focus groups with the caregivers to get their feedback on the system. Below is a summary of their positive comments:

- The automated system has reduced the paperwork and bureaucracy of the manual process.
- Caregivers felt greatly valued by receiving the mobile phone and were encouraged and motivated by it to complete their work.
- Households were intrigued and very positive about the mobile phone application.
- One caregiver reported being able to visit 15 children per day with the mobile application compared to visit 5 children per day versus the manual system.
- Members of the community are pleased to see their needs being sent directly to authorities.

Negative comments from the focus groups follow:

- One caregiver indicated that the desktop synchronization for the phone failed one time.
- One caregiver reported that the phone battery would run out of power and needed to be charged twice a week.

In terms of the battery charging issue, many of the caregivers paid to have their phones charged at a phone charging station. In a number of cases, the phone charging stations were not conveniently located. In the future, solar charges could be used to charge the phones. This is further discussed in the lessons learned section of the paper.

The GSM wireless communications network proved to be widely available and reliable for the regions of Zambia where the field experience was conducted. The average wireless communications cost to complete a mobile transaction was about $0.15. Industry experts, such as Louden [2009], suggest that GPRS/EDGE is more reliable and cost effective than GSM. However, from our field experience, the availability of SMS appeared to be much greater than GRPS/EDGE. This is based on the fact that our 3G wireless access for the Internet was very spotty in many parts of Zambia compared to the relatively common availability of a GSM signal from the mobile phone. It should be noted that JavaRosa supports GPRS and the development of GPRS appears more straight-forward given that you can assume the mobile

application runs in an IP-addressable space. Thus, there is no need to deal with multiple SMS messages for a single form instance since the data would be sent over the IP network and not as a series of SMS messages. In addition, this means that a GPRS-based system would not require the use of an SMS Receiver Service.

We completed a high-level estimated costing model to deploy the system across a typical World Vision program region. The model includes estimates for the following costs: communication, equipment, software and support. The model assumes that a typical World Vision program in Zambia will register 4,000 OVC in year 1 and 600 OVC per year thereafter. It assumes that the number of end home visits is 5% of the OVC population per year. It also assumes that 50% of OVC registrations will happen on the mobile application and 25% of household registrations will happen on the mobile application. Based on these assumptions, we estimated that the average annual cost to support the CHARMS system would be about $35,000. There would be one-time fixed costs of approximately $60,000 for acquiring the mobile phones, solar charges, servers and related system software.

4. RELATED WORK

There are a variety of platforms available for creating mobile phone-based applications for rural patient monitoring in the context of community health. By platform, we mean a set of factored out common services that can be used to construct specific mobile applications to support a particular form of field collection of patient data. These common services include the definition and rendering of data forms, the validation of data during entry and the transmission of the data over one or more wireless transport protocols. Some of these platforms focus on the development of the client-side mobile application. They require the development of a structured system for persistent storage, reporting and analysis of the data. Other platforms include a server-side component for managing the data collected via the mobile client applications. In this survey of related work, we focus on open-source platforms as we believe such platforms offer cost-effective options for mobile field data collection among not-for-profit organizations. For each platform, we also reference an example of a community health mobile application written using the platform.

Open Data Kit (ODK), discussed by Anokwa et al. [2009], is an open-source client and server platform for developing mobile applications based on the Google Android operating system. Thus, any Android-enabled device can be supported by the ODK Platform. The ODK is being developed at the University of Washington with support from Google. The platform suite includes three components: ODK Collect, ODK Aggregate and ODK Manage. ODK Collect allows for form design, rendering and navigation, repeating sub-structures and data entry validation. Forms are based on the XForms [2010] standard. ODK Collect supports the standard data types such as checkboxes and plain text entry plus a myriad of rich media data types, including photos, audio, video and barcodes. ODK Collect supports the GPRS wireless transport protocol and Wi-Fi for data transmission. Data can also be transmitted via a USB cable. ODK Aggregate is a Google App Engine cloud-based server that hosts forms and aggregates submitted data results. ODK Manage supports managing the deployment of the forms-based applications to mobile phones. A good number of projects use the ODK platform, including a Kenya-based project focused on mobile data collection for home-based counseling and testing related to the prevention and treatment of HIV.

JavaRosa [2010] is an open-source client platform for developing mobile applications based on the Java Mobile Edition (J2ME) operating system. JavaRosa supports a variety of J2ME-based phones, ranging from the Nokia 3110c to high-end smart phones. It includes support for user authentication, forms definition, rendering and navigation, as well as data validation. JavaRosa forms are based on the XForms standard. JavaRosa supports the GSM (SMS) and GPRS wireless transport protocols for data transmission. Data can also be transmitted via Bluetooth or a USB Cable. No significant server or deployment support is offered by JavaRosa. A number of mobile field data collection applications have been written using JavaRosa, including CommCare, discussed by Svoronos et al. [2010], and GATHERdata [2010]. CommCare is a community health data collection application. GATHERdata uses JavaRosa to deliver a

broader platform of support for mobile data collection applications, including server support for persisting and reporting on transmitted data. Our CHARMS mobile application was also written using JavaRosa.

RapidSMS [2010] is an open-source platform for developing SMS-based mobile applications. RapidSMS uses the notion of specifically defined and formatted text messages as the basis for its data collection. These text messages contain keywords that represent actions interpreted by a back-end web application to insert data into a database. The platform also includes workflow support that may trigger responses back to the user based on data received by the application. RapidSMS includes a web interface that allows users to view the data in the system. RapidAndroid [2010] is an implementation of RapidSMS that runs on the Google Android operating system. Several projects have used RapidSMS, including a project in Malawi to collect child nutrition data by Blaschke in 2009 documented by RapidSMS [2010].

FrontLineSMS [2010] is an open-source platform for creating SMS-based mobile applications. It also includes a Java-based simple forms management capability. FrontLineSMS does not require an Internet connection and allows field data to be stored on a laptop equipped with a SIM card. FrontLineSMS supports a wide variety of phones. It only supports the use of SMS for data transfer. It has been used in a wide variety of projects, including a project discussed by Banks and Nesbit [2008] at St. George's Hospital in Malawi where it has been used to support a rural healthcare network.

EpiSurveyor [2010] is a cloud computing based mobile data collection and reporting platform. It includes support for the design and deployment of survey forms on mobile phones to collect field data. EpiSurveyor supports a wide array of phones. EpiSurveyor also includes a cloud-based server environment for managing submitted form data and allowing this data to be viewed and analyzed via a web application. The data can also be exported in various formats. A number of EpiSurveyor community health mobile applications have been developed, including a project focused on containing a polio outbreak in Kenya described by the BBC News [2008].

OpenXdata [2010] is an open-source client and server platform for the development of mobile applications. It includes support for field survey form design and data collection. It also includes support for data validation. It includes server support for managing data collected via mobile form surveys. OpenXdata supports the GPRS wireless transport protocol. Data can also be transmitted via SMS and Bluetooth. OpenXdata supports a wide variety of phones. Cell-Life [2010] is a significant organization focused on the use of mobile technology to improve the lives of people affected by HIV in South Africa. Cell-Life is leveraging the OpenXdata platform in the development of its mobile community health applications.

The Nokia [2010] Data Gathering platform is open-source and includes client and server components. The platform allows for field survey questionnaires to be created via a web application and then downloaded to mobile phones for use. The mobile applications can run on any J2ME-enabled phone. Nokia recommends using smart phones such as the Nokia E71 and E72. Data collected via the mobile applications are then transmitted over GPRS or SMS to a MySQL database. A web application allows for reporting and analysis of the submitted data. A number of community health mobile applications have been written using Nokia's [2010] platform.

In the context of the related work, the CHARMS application suite is the first known fielded project that used JavaRosa to transmit mobile form data over SMS. In addition, it is one of the first known community health mobile application projects to be developed as a faculty-student service-learning project at an American undergraduate institution. The CHARMS application suite also contained some novel elements, such as reminder alerts to visit a specific child, that have not been widely reported on in the literature to date. Finally, the lessons learned from the CHARMS application field experience offer other researchers and practitioners insights about mobile field data collection and application development in a rural African setting.

In summary, there are a variety of mobile development platforms available for creating community health applications. These platforms are rapidly evolving and new platforms are likely to emerge in the near-future. Care should be taken to select the platform that best suites future mobile application development needs.

5. LESSONS LEARNED AND THE FUTURE

5.1 Benefits of the CHARMS Application Suite

The benefits of the prototype CHARMS system proved to be numerous.

- World Vision staff and caregivers were genuinely excited about the project and use of mobile phones.
- There were significant improvements in process efficiency and effectiveness (previously discussed) as the system simplified the overall process of data collection and reporting while improving analysis of data
- It demonstrates World Vision as an appropriate user of technology to donors, government and community members.
- It provides anytime, anywhere (Web) access to critical CHARMS data for World Vision staff on a global basis. Fully automated, on-demand reporting was also seen as a strong positive. Traceability reports to the individual level were seen as a huge value-add by staff. New Reports and analysis are now possible, including trend analysis, comparisons, etc. based on database-centered report/analysis capability.
- In theory, a donor facing application can be built to provide donors insight into ADP activity and results.
- By improving the quality, timeliness and completeness of CHARMS data process, beneficiaries (OVC) should be better served via active interventions, follow-up and analysis.
- It facilitates rapid field response to critical situations based on alerts and making critical information visible to the right people in a timely manner.

5.2 CHARMS Application Suite

The pilot in Zambia provided key insights into the benefits and areas of improvement for the CHARMS application suite. The lessons learned from the pilot project demonstrate the feasibility of such a technology to be used to help benefit rural communities and improve the quality of life.

5.2.1 Mobile Phone

The mobile device chosen proved to be a good fit; however, additional lessons learned became prevalent. The low-cost phone was a smart choice for both cultural and economic reasons. The rural villages where the caregivers volunteered were in poor standing. Thus, a high-end smart phone might have been insulting to the culture. Additionally, as World Vision is looking into mass deployment of a similar system, cost of tens of thousands of phones might be too drastic and unachievable. Overall, the low-cost Nokia handset proved to work well for the pilot.

A few observations demonstrated areas that would need consideration before a full deployment of the technology. The battery life and additionally cell phone features were quickly determined to be potential issues. For example, some of the caregivers used the phone for personal use, including features such as games, the camera, and even music. When the caregivers would use the phone outside of the mobile CHARMS application, the battery appeared to drain quicker. Therefore, one of the lessons learned for the cell phone is to consider locking down the phone and disabling functions to save battery life.

A few solutions to the battery life issue include solar chargers and weekly or biweekly charging at the ADP offices. Solar chargers can greatly benefit the caregivers as they would not be required to send the phones to be charged. The other option could incorporate current ADP staff trips to the villages each week to pick up the cell phones to be charged back at the ADP office.

5.2.2 Mobile Application

The mobile application proved to be quite successful in performing the function of a data collection device. Many design decisions appeared to work well, however improvements could have been made.

Despite initial worries, the learning curve for the multitap input system proved to be low. Even after the first day of training, most caregivers were inputting data into the fields without much difficultly.

The current XML parsing approach to data transmission and storage proved to be a tedious process. A small change in the forms translated to large overhead on reconfiguring the XML parsing engine. Other avenues exist including using binary representations of the form data and to serialize and deserialize the objects at the mobile device and the receiving database. Many foreseeable benefits to such

an approach exist, including added security, reduction in messages sent, and ease of extracting data from the message.

The actual mobile application's user interface could have been improved for an even shorter learning curve. For example, some of the forms from the CHARMS dataset appeared to be rather subjective rather than objective. By working with experts in the field, creating objective questions could save caregivers time from manually inputting letters into the phone by creating drop down lists to select from. This type of data would also greatly aid in a more granular and consistent analysis by World Vision managers and staff as trends could be more apparent with structured data.

The language barrier became an issue as most caregivers struggled to understand English. Therefore, native language support could greatly improve the data collected and ease of understanding for the caregivers. Additionally options could include the use of pictorial icons to represent questions as well to help the caregivers who struggle reading better understand the questions as well.

Finally, while the mobile device worked great to transfer data and review it from a web application, no reporting features existed to do longitudinal analysis in real-time during visits. For example, in the manual approach currently used, the caregivers use a paper notebook that tracks their visits. During a visit, a caregiver can easily browse over the past few entries to identify the child's status as better or worse. Thus, a feature to allow a caregiver to look at the past few entries could improve the visit quality with the mobile device.

5.2.3 Communications

The communications proved to be better than expected with satisfactory GSM coverage even in rural villages in Zambia. At every location we visited during our observation of home visits there was at least one bar of service and in many cases two or more bars of service. In fact, the average signal strength was 2.07 bars out of four.

The internet access proved to be more of a challenge and may potentially have a negative impact on communications above GSM. In our experience, GPRS coverage was spotty and often unavailable to use in most locations.

The use of an SMS communications service proved to work well for the application suite. Future considerations could include creating an in-country SMS receiver service to reduce the cost of long distance text message fees. Overall, the communications aspect of the project proved to be a positive experience.

5.2.4 Computer Application

The desktop application provided a reliable and scalable method for installing the mobile application, distributing client lists, and synchronizing data to the central database.

The phones appeared to provide enough local storage as to not be an issue with saved, unsent forms. Thus, data storage between synchronizations with the computer Bluetooth application did not prove to be a problem.

The desktop application worked rather well for most of the phones. However, one phone out of the ten had an issue with connecting to the computer application via Bluetooth. Additionally, some of the ADP offices do not have internet availability at all times. This fact demonstrated the need for a queuing functionality for the computer Bluetooth application to hold data before attempting to transmit over the internet.

5.2.5 Reports

The reporting engine worked well and demonstrated the advantage to the collection and storage of granular data. In fact, the creation of new reports was added to showcase the ease and power of the database and the reporting utility.

The reporting feature also proved to allow better knowledge and information for a variety of individuals. After the pilot project, it became apparent that multiple new reports could greatly aid in decision making for programme managers and the community chairperson.

The primary lesson learned with the reporting function was the benefit of structuring the CHARMS dataset into entity relationships. This structured format allowed for a multitude of report

possibilities to allow for global core metrics, national office metrics, ADP specific metrics, and even community metrics.

5.2.6 Alerts

Alerting seemed to be the function that can potentially have the most impact on communities themselves. By creating intelligent algorithms, automated alerts could be sent to ADP staff based on trends identified by the tracked indicators.

While the current implementation of the CHARMS forms was rather rudimentary, rules and smart algorithms could replace the human decisions of whether or not to send an alert. By deciding on a standard as to determine when to send an alert, the database can trigger meaningful email alerts to ADP managers who can quickly provide aid to an in-need child.

5.3 Service-learning Impact on Students

All students were required to produce a 3-5 page paper that chronicles their learning and discovery of community service throughout the semester. The instructor provided prompts throughout the semester for the types of information that should be included in the service learning and community engagement reflections document. These student reflection papers clearly demonstrated the profound impact that this service-learning project had on the students. The below excerpts from some of the student papers illustrate the impact of the project on the students.

- "While this has turned one of the greatest learning experiences of my life – it started out one of the rockiest! I can speak for the team when I say I felt in over my head in a sea of code and technological knowledge that I did not have any awareness of before this past semester. Mobile development was completely foreign to me. Words like open source, GPRS, JavaRosa, Parser, and SMS Receiver Service were being thrown around, and the learning curve seemed steeper and steeper."
- "This project has changed me as a student. I've learned so much in 8 months – I know anything is possible with determination and hard work. It has changed my outlook on the potential of technology to better humanity with the tools necessary to help people in need. This project has also changed me as a person. It has taken my Computer Science education at Messiah College and completely altered the meaning of it. I now fully understand the importance of using your major to glorify God. In my four years at Messiah, I worked to achieve high grades for my own personal standards – while I worked on this project, all I could think about were children who needed help. The project to me was no longer a letter grade, because you can't attach a letter to a child's life."

5.4 The Future

There are many future directions for this project. The current CHARMS prototype system was conceived as a field facing application with limited regard to the implications of the application and support required by regional offices and national offices in terms of reports, analytics, etc. In the future, consideration should be given to longitudinal analysis, comparative analysis across individual programs, countries, regions, etc.

Using the mobile platform opens a wide range of potential uses in the future. Health clinics could integrate with the system allowing for OVC referrals, appointments, and rapid response in emergencies. Similar to clinical algorithms is the notion we termed *support algorithms*. Such algorithms would allow caregivers to more objectively answer questions. For example, CHARMS asks the question: "Is the household poor?" Presently, the caregivers do not consistently answer this question using the same criteria. We are exploring the possibility to define criteria that would allow caregivers to consistently and objectively answer questions. Finally, the integration of GPS could allow WV to analyze trends and geographic coverage of programmes and OVC.

This work has been very well received by World Vision. World Vision is currently working with other large NGOs to obtain funding to support the development, deployment and support for a series of mobile application projects in the future.

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