Challenges of Operationalizing the Real-Time Biosurveillance Program's m-HealthSurvey

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ABSTRACT

m-Health applications, limited by the miniaturization aspects of the handhelds, cannot provide the extent of functionality that laptops or desktop-computers can. However, the reach of the wireless networks, mobility of the handheld communication devises, adaptability, and cost effectiveness allows for digitizing health information in the rural settings of Sri Lanka and India. The real-time biosurveillance pilot introduced m-HealthSurvey mobile application serves this purpose and makes use of the collected data to detect adverse events through statistical data mining software. Detected events are transmitted as situational awareness reports to health workers to intervene and prevent diseases from reaching the tipping point. Lessons to date point to field health workers being receptive to the technology that offers the incentive of replacing the ten kilograms of various paper registries they haul around during their door to door visitations. The present communication of health statistics, by post, takes up to 30 days to reach the decision and policy makers. Whereas, the m-HealthSurvey that enables on demand real-time statistics, with little doubt, proves to be a worthy advocate for rapid detection. Health workers in the field, serving low patient volumes, can self operate the m-HealthSurvey but healthcare facilities, serving higher patient volumes, require a data entry operator. Formal training and certification is necessary to implant the data entry as part of the patient care process opposed to a separate one. Policy intervention is necessary to ensure the reliability and accountability of the data submits.

Key words – m-Health, disease, surveillance, messaging, epidemiology, India, Sri Lanka

INTRODUCTION

Problem faced by the Health Officials in India and Sri Lanka is receiving health information in a timely manner in order to prevent diseases reaching epidemic states; as it was with the case of the Chickungunya viral fever in both countries in the recent past. The current Communicable

Disease Notification Paper System for “situational awareness” does not provide the much needed “real-time” information flow and analysis. The real-time communication shortcomings can be easily overcome with reliable and robust Information Communication Technologies (ICTs) and Intelligent Software.

The Real-Time Biosurveillance Program (RTBP) is a pilot project aiming to answer the question *whether software programs that detect events in health symbolic and categorical data sets and mobile phones that collect health data and receive health alerts are able to predict and prevent disease outbreaks in near-real-time*.

The RTBP is based on the concept of a predictor-corrector model for stabilizing the public health of a nation. The input to the system are simple environmental attributes, which are features such as the season and the day of week that cause trends in the data, and response attributes, which are the remaining features such as syndrome, diagnosis, gender, and age. The output generated by the system is the detections of possible disease outbreaks or patterns of adverse events [Sabhnani et al, 2005]. The feedback loop for error correction is the intervention and prevention actions to minimize the health risks.

The actors of the system are health care providers: medical officers, primary health care workers, clinicians and health officials: monitors, decision-makers, and policy-makers. Health content interchanged between the various health workers and health officials range from patient case information (case reported date, disease, syndrome, gender, age, and location) to event detection information (time series and spatial data) to standardized alerts (situational health reports).

The success of the introduced ICT depends not only on the quality of the technology artifacts but also on the actors (i.e. the people and the organizational environment) [Ammenwerth, 2004]. Hence, there are three main components that the research will evaluate: the workability of the technology in the given environments (whether the technology can actually live up to the expectations), understand the set of newly introduced processes that impact the human element (will it aid the healthcare workers with the protocols as it was proven to be the case in the Uganda study [DeRenzi et al, 2008]), and the policy implications (are the health workers and epidemiological units ready to accept the changes; i.e. business process improvements or re-engineering).

There are other initiatives of similar nature – use of mobile phones (or m-Health programs) to combat epidemics. Three such applications are the Cell-Life, Episurveryor [Kinkade and Verclas, 2008] and e-MICI [DeRenzi et al, 2008] developed for monitoring epidemiological information. However, those applications are geared for collecting data on specific known diseases, namely HIV/AIDS, Tuberculosis, Malaria, Child illnesses, etc. Moreover, these applications, at present, run on high end mobile phones or PDAs. The difference that the RTBP developed m-HealthSurvey, besides working on around US dollar one hundred mobile phones, is that it is designed to survey all patient cases (disease and syndrome) as disease surveillance systems should not only progress towards various specific disease but monitor non-communicable disease as well (i.e. all diseases) [WHO, 2004].

The RTBP is currently under pilot testing in the state of Tamil Nadu in India and North Western Province in Sri Lanka. The introduced technology based program comprises data collection, processing, and reporting functions. This paper will mainly discuss the m-HealthSurvey J2ME mobile application used for data collection and discuss the implementation challenges with some observations from the initial stages of the evaluation phase.

RTBP PROCESSES AND INFORMATION FLOW

Implementation of RTBP essentially means to make available the right information at the right place, at the right time and in the correct form [Ganapathy et al, 2008]. In that respect, this section discusses the responsibilities of the various actors, the involved processes, and the information flow. The information flow completes a cycle where information provided by health workers is processed and resulting decisions are communicated back to the health workers. Steps 1 through 8 illustrated in Figure 1 discuss this information cycle in the section below.

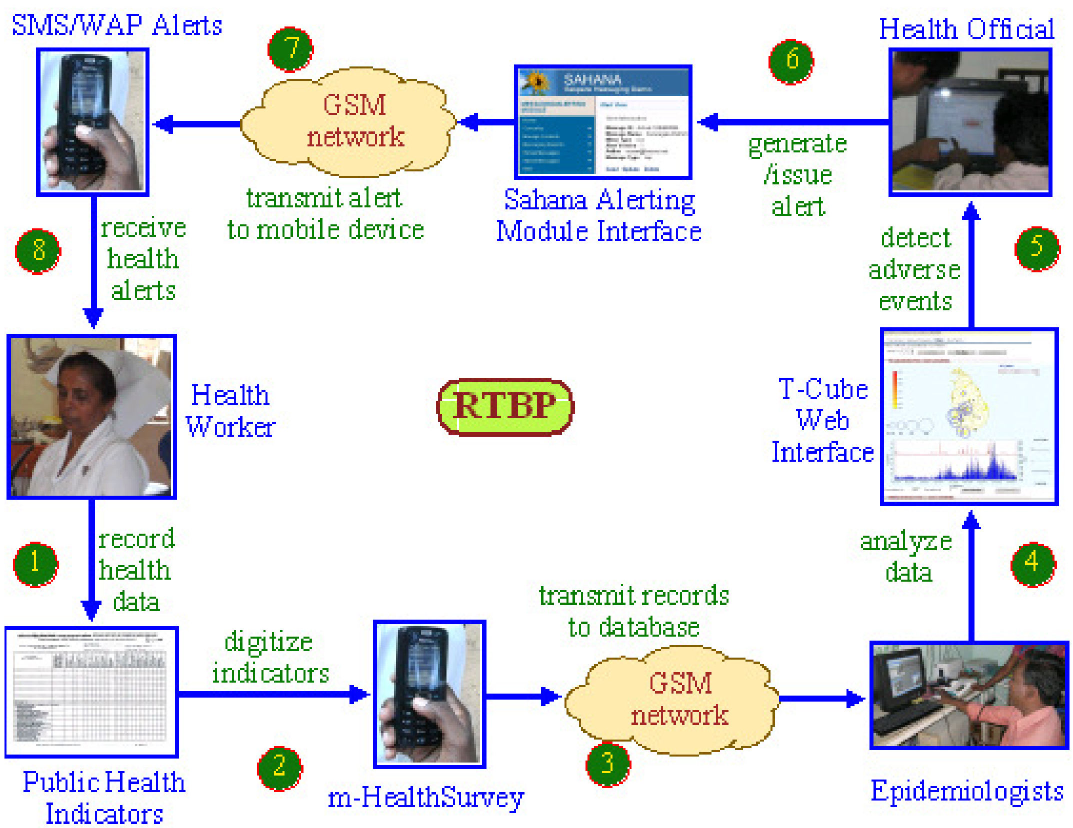

Figure 1 RTBP actors, ICTs, processes and information flow

Step 1 – Health workers record patient information in various registries such as outpatient registry, inward registry, morbidity report, etc. Once policies are in place for a wider scale deployment, the paper registries can be obsolete and same data can be supplied via electronic means; i.e. skip directly step 2.

Step 2 – Patient complained symptoms, healthcare provider identified signs, and diagnosed disease along with patient's gender, age, and point of care location (i.e. hospital, clinic, or village name) are entered in to the m-HealthSurvey mobile application.

Step 3 – Information is sent to the central database through the GSM cellular network over the GPRS transport layer. In the event the signal is absent, the record is stored in the offline storage in the mobile RMS (Record Management System) until connectivity is established and data is transferred.

Step 4 – Periodically (on the average once a day), Epidemiologist analyze the information using the T-Cube, time series and spatial scan, web interface software. The data is also subject to automated event detection handled by software algorithms that are scheduled to run once a day. These algorithms will issue alerts to the Epidemiologist of detected events that may be potential disease outbreaks.

Step 5 – If the Epidemiologist detects an adverse event, then a decision is made whether or not to intervene.

Step 6 - Events of interest (or adverse events) that require intervention and prevention or are worthy of notifying are communicated to those health workers in the effective geographic areas, and in certain cases notify a geographical spread wider audience of health workers. Structured, Common Alerting Protocol (CAP), messages are generated and issued through the Sahana Alerting Module by the authorized health officials.

Step 7 – A tone down version of the CAP messages that can fit in a SMS are transmitted via GSM cellular networks to the health worker mobile phones. The complete CAP message is published on the web for health workers to access through WAP.

Step 8 – Based on the situational reports (i.e. CAP health alerts) received the health workers, if necessary, activate relevant response plans.

HEALTH WORKERS SUBMITTING DATA

Sri Lankan health workers

The RTBP pilot is taking place in four Medical Officer of Health Divisions (Wariyapola, Udubeddewa, Pannala, and Kuliyapitiya) in Kurunegala District, Western Province, Sri Lanka. The design in Sri Lanka involves sixteen Sarvodaya Shanthi Sena's Primary Healthcare Center Volunteers, recruited as Research Assistants for the project, residing in the four mentioned MOH divisions in the Kurunegala district of Sri Lanka. Sarvodaya is the largest NGO in Sri Lanka and has established 450 primary health care facilities in chosen villages that fall under the Sarvodaya Comprehensive Community Healthcare Program (CCHP). These facilities are named as "Suwadana" Centers. The sixteen Suwadana Center Research Assistants (abbreviated as Suwacevo just in this paper) are trained Primary Health Workers. These primary health workers have been given a mobile phone and training to operate the m-HealthSurvey application. They visit government and private healthcare facilities in their periphery to collect the health data through the m-HealthSurvey. They visit health facilities and general practitioners in their respective areas, approximately, 3 to 4 days a week, depending on the frequency of patient visitations.

In the Sri Lankan case, the hospital outpatient/inward registries, MOH office registries, and PHI offices registries maintain vital patient records. The essential data that is picked out from these registries are the age, gender, syndrome, disease, date case was reported, location of the patient visitation (i.e. town/village of hospital or clinic). The present disease surveillance and notification system is of Sri Lanka is explained in the RTBP user requirement specifications [Hewapathirana et al, 2008].

Tamil Nadu health workers

Design in Sivaganaga district comprises of twenty four Government Health Sub Centers (HSCs) and four Public Health Clinics (PHCs). Of the RTBP collected data, the HSCs account for 30% of the patient records and the PHCs the remaining 70%. The VHNs running the HSCs (in most cases out of their own home) and Staff at the PHCs were given mobile phones and trained to operate the m-HealthSurvey mobile application for sending the required data.

VHNs, in rural Tamil Nadu, besides running the HSCs, also make house calls, conduct clinics in schools, and facilitate other health programs. On average, a VHN will cover 7 – 10 villages. Some of the services the VHN provide are - antenatal care, maternal care, immunizations, investigating communicable disease cases, and primary healthcare. The VHNs maintain twenty different registries to record information pertaining to the services/programs. The main registry relevant to the RTBP is the "morbidity" and "communicable disease" reports. The twenty registries are then consolidated in to sixteen reports by the Sector Health Nurse (SHN) at the PHC before entering that data in to the Directorate of Public Health and Preventive Medicine web based information system administered by the National Informatics Center of Chennai.

The PHCs that provide specialized services like child delivery, ECG, and general medicine. The SHN is one of the staff members at the PHC and supervisors the VHNs attached to that PHC division. The other staff members at the PHC are Medical Officers and Nurses. A single PHC may cover over fifty villagers and employ 5 – 8 VHNs. To understand the present disease surveillance method and organizational structure of the state of Tamil Nadu, the reader is encouraged to refer to the real-time biosurveillance program: user requirement specifications [Hewapathirana, 2008].

The Medical Officer at the PHC, examining outpatients, maintains an outpatient registry, which notes the patient's annually assigned health record serial number, the date, diagnosis, and treatment. The Nurse or the SHN, working at the PHC, will enter the outpatient data along with other medical service data in to the m-HealthSurvey.

THE m-HealthSurvey FUNCTIONALITY

The m-HealthSurvey software application is a J2ME midlet built on top of the mobile API java stack that specifically uses MIDP2.0 (Mobile Information Device Profile) and CLDC1.1 (Connected Limited Device Configuration) JSR (Java Specification Request) components. This allows the application to be ported on to any mobile phone that supports the MIDP2.0 and CLDC1.1 java components designated for J2ME applications to transparently interact with the mobile device display/controls and connectivity, respectively. The m-HealthSurvey software specifications [Kannan et al, 2009] describe the technical details.

The m-HealthSurvey is made available as a WAP download through GPRS. The user has to simply type in the URL (e.g. http://www.rtbp.org/dwnld/lk) in the WAP browser. Although the application is generic and can be applied to any country for the simple purpose of collecting patient disease/syndrome information, the attribute names on the mobile application forms and the URL that points to the implementation specific database must be hard coded. For instance the field health workers collecting data in Tamil Nadu are the VHNs and the equivalent in Sri Lanka are the Suwadana Center RAs. These country specific names must be customized. The m-HealthSurvey communicates data with the database through HTTP Post, request, and Get functions through PHP hypertext preprocessor that follows a REST (Representation State Transfer) like architecture [Fielding, 2000]. The application requires a URL (Uniform Resource Locator) for networking and that URL has to be embedded in to the mobile application. Hence, some, unavoidable, implementation specific customization of the application is required.

The main menu of the m-HealthSurvey comprises: download list, profile, location, offline survey, and health survey, shown in Figure 2 (a). After installing the application the first step is executing the *download list* function which will retrieve the lookup values from the database such as the list of disease, sign, symptoms, age-groups, gender names, case-status values, location types, and health worker types. This is usually a onetime step but the users are encouraged to execute this function from time to time to update the list of disease, signs, and symptoms on their mobile phones. The user must register their health worker ID (employee ID), first/last name, email, and phone number in the database through the *profile* registration process (Figure 2 (b)). The application allows for multiple profiles permitting for more than one health worker to share the same mobile phone. Next the users must identify the villages they work in, which is facilitated through the *location* menu. The health worker selects their jurisdiction type; i.e. the administrative geographic area name; followed by entering the name of that area (Figure 2(c)). For example, location type = “PHI” (Public Health Inspector) and the location name = “Kuliyapitiya” would retrieve all the villages belonging to the Kuliyapitiya PHI area. These values will have to be pre-populated in the database first. Once the static (lookup) values are downloaded, profile is registered, and locations are identified, user is fully configured to begin submitting health records; else the application will not allow the user to proceed with submitting health records without the initial three step setup.

Attributes of the *health survey* form are – case date time, health worker id, location name, patient first name, patient last name, notes, gender, age-group, disease, symptoms, signs, and case-status (Figure 2(d) and 2(e)). In the first screen of the health survey - the date and time are automatically set to the current date and time taken from the mobile phone, anticipating the health workers will be entering the data in real-time (i.e. at the same time of examining the patient) but gives them the preference to change. Health worker Id, location name, age-group, gender, and status are pre-populated drop down lists that are initially set through the download, profile, and location menu functions during the three step setup process. For confidentiality, the project's initial design had not incorporated the patient's name; however, the Tamil Nadu health workers insisted that these fields be included. However, these values are optional. In the Sri Lanka case these fields are disabled (i.e. hidden) as they are not a requirement.

If the patient is diagnosed, in screen two of the health survey menu function, the user can specify the disease by typing initial few characters of the disease name in the search disease textbox which will populate all the names of all the diseases with corresponding spelling in the disease dropdown control. The user then selects the right one from the list. Upon selection the list of associated symptoms and signs will be automatically populated in the respective textbox controls but giving the user the rights to edit the list as required; i.e. add or delete the list with respect to the real scenario. If the patient is not diagnosed but symptoms are identified, then the user sets the disease to "unknown" and simply fills the symptoms and if the signs are known, then enters the signs as well. In the event a disease is not in the mobile phone memory, then the user selects "other" as disease name and enters the new disease. When the server receives the record and validates the disease to be absent in the database, it will include that new value in to the database's disease list. Same rule applies to unlisted symptoms and signs. Location, symptoms, age-group, and gender are the mandatory fields (marked by an asterisk * next to the attribute) that must be filled to successfully submit a record; else the application will prompt the user with an error.

One reason to minimize the amount of data to be entered and allow for mostly selection from lists is to minimize on the data entry time because the expectation is to incorporate the data entry as part of the patient care process rather than a separate task. It is expected for a singe record entry and submission to take less than 15 seconds.

The application uses the standard top left and right buttons, the ones used by all mobile application to go back to the previous menu or select a function, to navigate back to the previous screen, hop to the next page, rest the attribute values, save the records, or update the records.

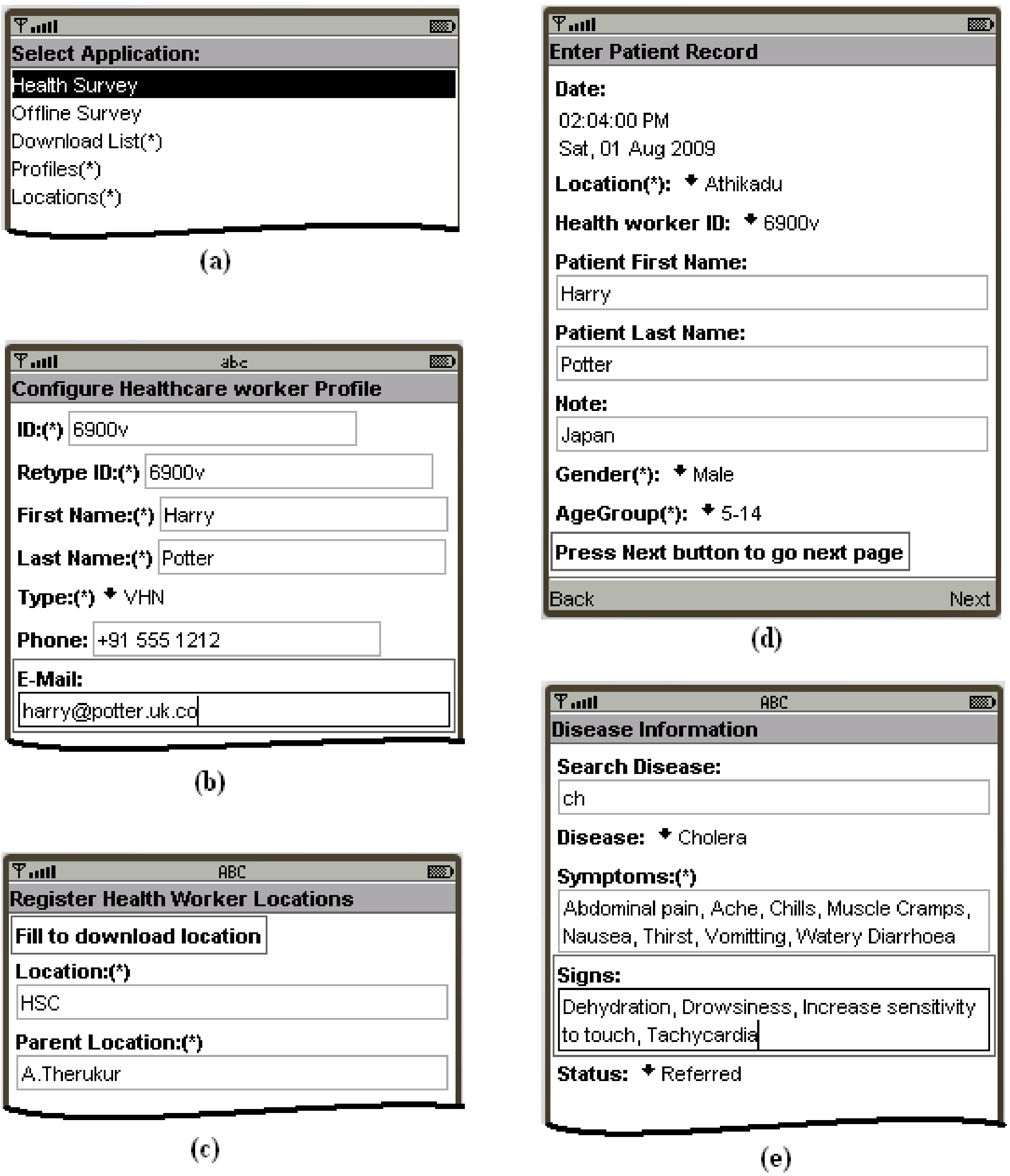

Figure 2 m-HealthSurvey Screens (a) main menu (b) profile (c) location (d) patient record page 1 (e) patient record page 2

EVALUATION METHODS

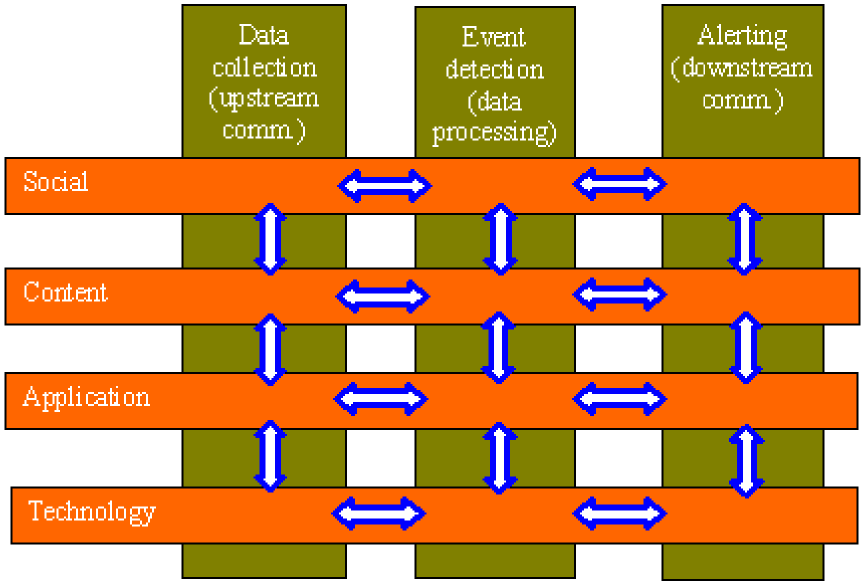

Figure 3 Vertical components of the RTBP communication structure and horizontal layers of each component with arrows depicting the interoperability

With respect to the information flow cycle illustrated in Figure 1, the technology design is partitioned in to a set of data collection, event detection, and alerting vertical segments as shown in Figure 2. The vertical segments are, further, horizontally partitioned in to social, content, application, and technology layers (Figure 2). In this paper we mainly focus on describing the methodology of the four layers corresponding to the data collection vertical and in some cases the contribution of the data collection to the neighboring event detection vertical at the relevant layers.

Ammenwerth et at, 2004, have summarized a broad set of evaluation criteria on the usability of the technology, affect on structural or process quality, investment and operational costs, problems associated with daily operational costs, and social consequences of introduction the technology. Wagner, 2008, and Lewis, 2002, have proposed biosurveillance system evaluation methods. The RTBP research adopted some of these methodologies. In general the social, content, and application layers of the mobile application will be assessed through a set of focus group interviews and usability questionnaires. The transport layer will be assessed on the basis of the cost benefits and access factors.

The project intends to execute simulations to evaluate the reliability and effectiveness of each of the verticals; where the data collection vertical will be the first to be put to the test. The process would include comparing the proposed system to the present system. Both in Sri Lanka and India, the epidemiology units consolidate weekly disease count reports. A one month time period would be picked-out where a significant increase in one or more diseases occurred. The researchers would study this event of interest as to how, who, when, and where the incident was detected. The weekly disease counts for that particular period would be used to generate a random set of patient complaints [Lotze et al, 2009]. 95% of the random data set will be directly uploaded in to the database; while the other 5% will be distributed among the health workers to manually enter. In this activity the project will observe the performance of the data entry process and accessibility aspects. Thereafter, conduct a set of interviews and offer a set of questionnaires for the health workers to share their opinions.

DISCUSSION

The discussion in this section is based on the preliminary assessment of the data collection element. Observations were made though interviews and monthly meetings conducted with the health workers in Tamil Nadu and Sri Lanka. This paper will discuss the following - At the social layer discuss the health worker training regime, reliability, and other applications; at the content layer discuss the availability of information, constraints, and data sensitivity; at the application layer discuss expectations and benefits; finally at the transport layer discuss the transmission costs, latencies, and redundancy. The paper does not discuss results of any simulation activates because they ha not been carried out at the time of submitting this paper.

Effectiveness of training regime

Health workers who had not used a mobile application or even SMS prior to the project introducing the m-HealthSurvey, with a one day training session, were able to adapt to the newly introduced technology. Immediately after the training, health workers began submitting health records via the mobile application.

Six weeks after the initial training, researchers visited with health workers to the progress in data entry capabilities. There are significant differences in the level of participation among health workers entering data into the m-HealthSurvey application. Some health workers noted problems with the application itself in terms of entering or deleting symptom data.

Finding time to complete the records without disrupting current workflow may be a significant barrier to adoption for the study, as several health workers mentioned this in their comments during group meetings. 50% of the health workers chose to enter the data at the end of the day; while the other health workers either entered data every 2 – 3 days or on the weekend. However, all of them complete the paper work that is enforced by the government system regularly as required. It is evident that policies are put in place and superior intervention is needed to enforce the electronic data entry process as part of the routine patient care process.

In several locations it was apparent that some VHNs have not entered many (if any) records into the system so far. Following, the periodic intervention of trainers, on a one-on-one basis, has shown signs of improvement in the data entry. The learning curve is slow and progressive but has not achieved the anticipated magnitudes.

VHNs in one PHC division also expressed some confusion about the scope of record entry. They had believed that the requirement was for communicable diseases only; however, they were told that record entry included all diseases.

Health Worker reliabilities

Health workers in Tamil Nadu noted concerns with completing the case-status treated/referral field, indicating a conflict with their professional ethics or practice in terms of treating patients. In the system this attribute reflects on the status history of the patient case. This specific set of health workers had submitted significantly low count of records relative to the rest. When questioned, the researchers revealed that they had cheated on the reporting because they did not have adequate medical supplies at the HSCs and had to refer the patients to the Public Health Clinic or other larger hospital. There was apprehension because having reported the true patient visitations and mentioned "referred" in the records would alert the health officials to question them as to why they had not treated the patient in that circumstance. This action of referring patients is not the fault of the VHN but more the Government's weakness in supplying adequate medicine to those HSCs. However, it is culture in the subcontinent for sub ordinates to be passive and not question or complain about the deficiencies in the system or higher authorities.

For the purpose of detecting health events through the RTBP system, the field values of the patient's case status: referred or treated is immaterial. What is essential is the patient complaint; i.e. syndrome information along with the gender, age, and location. The recommendation to include the patient case status was of the health workers' idea, which in some sense backfired or identified a flaw in the present system. To ease the fear the project made the patient case status field an optional entry giving the choice of submitting a null value.

It is uncertain as to the health workers submitting the entire set of patient complaints. Currently, it is anticipated until the health workers are fully confident that they may be shy in sending some of the data. The Researchers learned that each clinic or hospital server 100 – 200 patients a day; some larger hospitals even 500 patients a day. The field health workers examine from 10 – 30 patients a days. Based on these numbers it is anticipated for each division (PHC division in Tamil Nadu and MOH division in Sri Lanka) to submit a minimum of 3000 records per week. However, the data rates observed over the first eight weeks fall short of the anticipated number. Unless the actual numbers are received, it is questionable whether the detection and analytics algorithms that work on Bayesian neural networks would be pragmatic in realizing the actual scenario.

Issues with content

Not providing the users with a prefabricated complete list of diseases and syndrome information to select from rather than type, has lead to inefficiencies in data entry and submission; one of the problems being, the users less proficient in health terminology as well as the English language misspelling or as few of the diligent Sri Lankan health worker, taking up time to find the correct spelling through other means. Another problem with inaccurate spelling is it leads to problems with integrity of information in the database and produces inaccurate statistics.

A few minor concerns with the application were noted at various locations. Chief among these are minor issues with symptom and sign data. In particular, users wanted a greater range of symptoms to add to their entries. As a result they took more than 2 minutes to enter each record. A glitch with deleting symptoms from certain diseases was noted as well. The Sri Lankan Sarvodaya Suwadana Center health workers submitting the data reported inadequate content in relation to the disease, symptom, and signs where they had difficulties with entering additional symptoms or signs due to the incompetence in English spelling.

With the option of allowing to type symptoms and signs, the sluggish users would not include the true patient complained set of symptoms or observed signs. As a result the application was revamped to provide all possible symptoms and signs for the each disease. This intern takes a toll on the available memory. With the complete list the health workers entering data only have to delete the symptoms and signs inapplicable to the particular patient case, which is much faster than adding (typing). However, it was evident that those who submitted data the fasted did not bother to edit the list; while those who prolonged were diligent in ensuring that the record reflected the true patient case classifications.

Localization of the application was mentioned at one location (e.g., Tamil version) but it was also noted that English would be sufficient for most transactions at this time. One health worker, in Sri Lanka, had taken the initiative to prepare a list of disease names in English and corresponding Sinhala (local language) terms to help with the working language deficiencies; the list would be shared with the rest of the health workers. The Indian health workers expressed the same concern with inadequate list of diseases and complete symptoms and signs.

A key issue the project faced was finding a freely available database to acquire the full list of disease and related signs and symptoms to upload to the database. It is possible to find websites such as MedicineNet (http://www.medicinenet.com/symptoms_and_signs/article.htm) but they all require money to share their database, this applies to the World Health Organization (WHO) as well. As a result the project has taken steps to develop this database and make it available as free and open content for others to adopt in the future.

A possible drawback is the limited internal memory of the mobile, which is confined to 2MB. The application itself takes up only 22Kb and the mobile phone allocates a maximum 1MB heap size to the java application. Given the vast number of diseases and the various sub classifications of diseases the ICD-10 (International Classification of Diseases) list given by the WHO is near 20,000. Most of the classifications are constructions describing the consequence of the pathological process and not necessarily worth storing. However, minimal list still is quite large. Each disease, symptom, and sign relationship record takes up 0.5KB of memory, implying the 1MB heap can hold only 2000 records. For the time being the project has implemented the top 100 diseases and hopes to gradually grow the list. By the end of the one year evaluation period the researchers would have a clearer understanding of the optimal list of disease, symptoms, and signs.

Data sensitivity

It is the ethical responsibility and requirement of an effective disease surveillance system to maintain and protect the confidentiality of personal identifying information. It is important to prevent willful and accidental misuse of such data for profiling and linkage of sensitive data to any specific individuals [Garg et al, 2005]. The state of Tamil Nadu health workers insisted that that the patient's name and address be included. Evidently to follow-up with the patient if required. Given that, on the average, one member of each household is employed overseas, and in the event, during an home visit, they seek healthcare from a local PHC or HSC, the health workers need to track the overseas employed patient's foreign address, incase it is an infectious disease and the patient needs to be contacted.

The data recorded through the mobile phone is not stored in the phone memory after submitting the data to the database. This prevents anyone with access to the health worker's mobile phone from accessing the sensitive data. The database stored data is only accessible by authorized persons through a secured web interface through an authentication process on a need-to-know basis.

Adoption of content standard

Given the objective of the proposed system is to rapidly detect diseases; the upstream information (i.e. data collection) must provide the mandatory information for the event detection algorithms; as shown in Figure 2 with the arrow between the data collection and data processing verticals in the content horizontal layer. This set has been identified as the *case-time, symptoms, and location*. However, extending the minimal set of information to include information on *disease, signs, age, and gender* can improve the analysis that will lead to finding alternate correlated trends.

HL7 standard (Health Level 7th) provide a framework (and related standards) for the exchange, integration, sharing and retrieval of electronic health information. Specifically the HL7 chief complaint data contains the patient's symptom, in most cases recorded by a nurse; where symptoms are the ailments the patient complains about. Kurtz et al, 2008, have shown that the HL-7 Miner, a near real-time disease surveillance and monitoring system, can effectively predict outbreaks simply analyzing correlations in clusters of patient chief complaints (symptoms). The m-HealthSurvey has made case-time, symptoms, location, gender, and age-group as mandatory attributes of a health worker submitted health record. Attributes such as location, gender, and age-group increases the evaluation data space to find spatial and human classification specific correlations in the health record sets. Therefore, the project is confident that the essential elements required adapting to the HL-7 standards, for the purpose of disease surveillance, has been met.

Design obstacles of the application

A top-down bottom-up approach was used to develop the mobile application. At each stage of the development cycle the users (health workers and other stakeholders) were consulted to ensure that the software deign complied with the requirements. In some instances, user requests had to be denied in order to stay on track with the project's objectives. However, these requests were noted and if applicable, will be incorporated in to future designs or at the time of full-scale implementation. There were no technical mishaps in the application and worked as designed.

There were some problems associated with usability. An informal set of Time to Complete (TTC) measures were taken and results indicate a range of proficiencies in using the m-HealthSurvey application. Average times were about 2 minutes per record, although this might be improved through training and practice. The project set standard is approximately 15-20 seconds per record. As a result it was recommended that a training and certification program be introduced to ensure reliability of data submission as well as supervision at regular intervals.

Since the RTBP was an innovation the technology developers, at the beginning, were unclear of the scope of the project specific requirements as well as thinking of the design in an abstract perspective. The application developers were trying to build a single customer specific solution for a particular implementation or in some cases computerize the existing paper system. It was important that the design of the m-HealthSurvey be generic and can be easily adapted to any implementation that serves the purpose of data gather for the purpose of disease surveillance.

The RTBP focus is proving the concept of the system; thus gathering health data. As a result, during this phase, the project will not evaluate the vulnerabilities and security threats the system is prone to. Risks associated with wireless networks and hand-held devices and the solution to overcoming security threats are extensively discussed in [Tom K. and Les O, 2002].

Data transportation costs

"With reduced needs for cable installation and maintenance, wireless infrastructure is less expensive and faster to deploy. The capital cost of providing mobile coverage is about one-tenth the cost of installing a fixed-line connection. Wireless infrastructure is less susceptible to theft or vandalism, as may be the case with copper lines. Wireless also has the added benefit of being usable for portable and mobile applications, as well as fixed ones" [Ganapathy et al, 2008].

The global market price of a Nokia 3110c mobile phone is US$110.00 (India with 512Kb T-Flash external memory US$90.00 and Sri Lanka no external memory US$125), which includes features such as edge, 2MB internal heap memory, and total 9MB internal memory. Assuming the mobile phones will last 1 year (i.e. depreciated over 1 year) the cost per hand set per month would be US$7.50 and US$10.42 in India and Sri Lanka, respectively.

The Indian package at ~US$4.80 per month includes 50MB of free GPRS data transfer, which amounts to ~US$0.1 per 1MB. In Sri Lanka the package does not include free GPRS time but the price is as low as ~US$0.2 per 1MB for data transfer. Each m-HealthSurvey submitted record takes up approximately 2KB. A health worker submitting an average 100 records per day over 30 days would accumulate to 1.2MB, costing ~US$0.11 and ~US$0.24, per health worker per month in India and Sri Lanka, respectively.

The combined cost of the hardware and tariffs will amount to US$7.61 and US$10.66 per health worker per month, in Tamil Nadu and Sri Lanka, respectively. The researchers are yet to compare these numbers with the present system. This paper is unable to report on the comparison due to lack of evidence on the present costs, which may take sometime to gather and calculate.

Satisfactory transport Layer

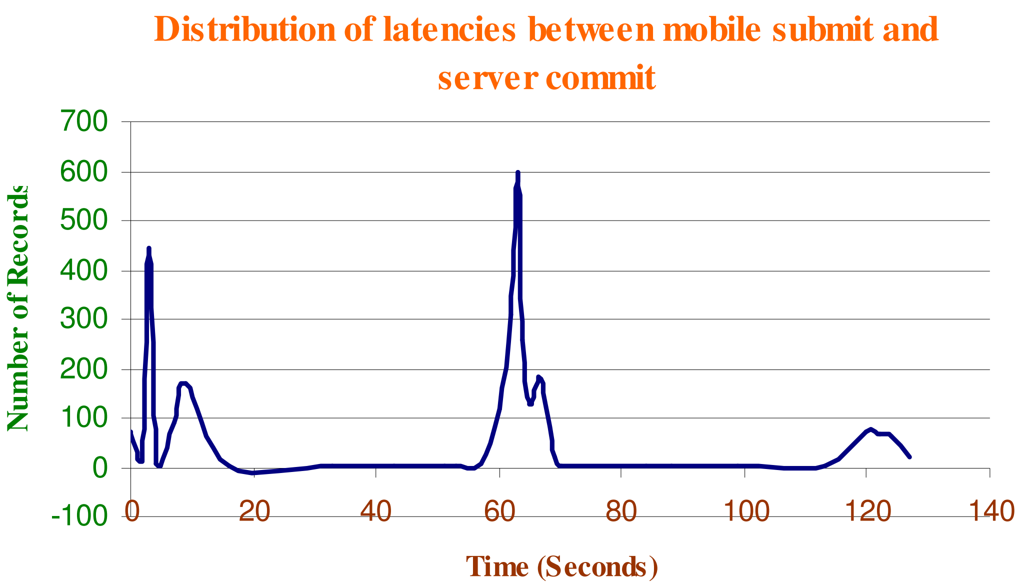

Figure 4 Latency distribution plot of number of records vs. time

At the time the mobile application submits the data a timestamp: mobile date-time, based on the date and time on the mobile phone, is added to the data string. When the record is saved in the database, the date-time of the server is recorded as the create-date-time. Two thousand six hundred and sixty three (2663) records submitted by health workers over the past month (15 June 2009 to 15 July 2009) were examined for latencies. Figure 4 shows the distribution of the latencies (i.e. time difference between the mobile submitting the record and the server committing the record to the database). Figure 4 shows the latencies to be clustered around 0-5, 5-20, 55-70, and 115 – 130 time intervals; with 90% of the records to be around the combined time intervals 0-20 and 55-70 time intervals. There is no correlation of the latencies with the time of day either. Only conclusion that can be drawn is that the health worker mobile phones are not synchronized with the server time. Therefore, the calculation may not be quite accurate. However, the latencies are well within the tolerance range.

Table 1 Probability distribution of the latencies in Figure 4

Time intervals	0 – 5	5 – 15	15 – 55	55 - 70	70 - 115	115 - 130
X =	0	1	2	3	4	5
Pr(X=x)	0.2036	0.0995	0.0023	0.6091	0.0019	0.0837

There are shadow areas where the connectivity is weak. However, this is not an issue because the m-HealthSurvey has the capability to buffer records when offline and later submit when connectivity is strong. In one occasion the network operator was performing some maintenance operations, which resulted in loss of connectivity. These types of latencies are once in a blue moon type of events that will not harm the overall performance of the system. To date there has not been any loss of data communicated through GPRS; i.e. all records submitted had been received.

Discarding SMS as a transport

The RTBP in its proposal had envisioned transmitting health data through SMS. This was to complement the GPRS transport and work in situations when GPRS was not present. SMS is effective with low signal strengths. One major dilemma in SMS is that it is a push protocol and cannot pull information. Therefore, it would be necessary to build a transport layer based on SMS just for the m-HealthSurvey application to talk with the server as well as develop an object to manage the sequencing of SMS pages that not necessarily would arrive in the required order. Additional work would be necessary to create a class that could parse the stings in a similar way HTTP Post, Request and Get function operate. The second issue with SMS is the cost; where the cost to transmit the same piece of information would cost twenty five times more than GPRS. Given that GPRS networks are getting more robust each day, the additional cumbersome transport layer development and the relative cost of transporting records, the project decided to forego the idea of adopting SMS.

Some benefits the mobile software offers

Conventional methods of reporting standard notifiable disease, by postal service, will take up to 10 days [Hewapathirana, 2008]. The propagation of health statistics, up the chain to District and State/Provincial administrative levels, can take up to 30 days. Reporting patient via the m-HealthSurvey is near real-time. Submitted data is immediately available in a database for the State/Provincial health officials. As such, there is little doubt that the mobile phone can reduce reporting times significantly, provided that field staff uses it reliably and consistently.

In Sri Lanka and India, patient records are maintained in registries. Hospital or clinics maintain Inward and Outpatient registries. The field workers have their own set of registries categorized by the curative or preventive program. The statistics are consolidating at the divisional level and summaries are passed on to the district, state, provincial, and national layers, up the chain. Policy decisions are taken at each of the layers. By digitizing the data at the point of care nodes will eliminate the need for manual painstaking processes of aggregating statistics at each of the layers. As a result, the m-HealthSurvey will complement the presently practiced data analysis but can be done with s few clicks of the mouse on a computer linked to the database that stores all the health worker submitted data.

The present system does not have a complete disease guide or reference material that a health worker can use to find out about a particular disease's symptoms and signs; whereas the m-HealthSurvey can be used as a mobile reference tool to find out the symptoms and signs of a particular disease. There is no additional cost associated with the search. On the contrary using the mobile to search from the web and receive the data would incur a cost.

Given that the research team was unable to locate a World Wide Web source to locate a freely assessable database to obtain the list of disease and associated symptom and signs, the data had to be manually entered in to the RTBP database. This list will be made available as free and open content for future implementers to use, which would reduce their implementation of disease, symptoms, and signs list to zero.

Other implementation aspects require identifying the locations; i.e. hospitals, clinics, geographic administrative structure (district, division, area, etc), and villages. The steps involved with this part of the implementation takes up time to gather the information required and enter this information in to the system. This action is specific to each implementation. However, the benefit is that the same locations identified in the database required for the m-HealthSurvey would apply to and will be used by the event detection and alerting technology components described in Figure 2. The same location database can be used in other health administration compliant electronic systems.

Other relevant uses of mobile phone

There is evidence of social networking through the use of ICT. In Sri Lanka the recruited Suwadana Center health workers had not known each other prior to the project and it was the project that made the acquaintance. Ever since then they have been communicating via SMS and Voice on various matters. In most occasions it has been on informing each other of significant diseases emerging in their villages such as the dengue outbreak occurring in Sri Lanka.

The Sivaganaga District Deputy Director of Health Services office uses a freely available SMS portal: www.way2sms.com , to schedule important and emergency meetings with Medical Officers in their jurisdiction. However, a limitation in the free SMS portal does not allow for scaling beyond the group of Medical Officers. The Sahana Alerting Module (SAM) was mainly introduced by the project for the purpose of notifying health officials and health workers of adverse health events but also capable of being adopted for other notifications such scheduling emergency stakeholder meetings. Health officials in Tamil Nadu and Sri Lanka are very keen in this application.

CONCLUSION

The m-HealthSurvey was accepted by the health workers from an early stage when they realized the potential of rapid communication of field and facility health data instantly for the purpose of disease surveillance. However, after beginning to use the application the health workers have identified issues associated with social issues and the application's functionality. There are unanswered questions that the RTBP needs to assess through simulation in terms of the reliability and effectiveness of the technology on the long run as well as the interoperability of the m-HealthSurvey with the binding data processing and alerting components that completes the information propagation cycle. It is too early in the study to realize the impact of the RTBP on the overall health sector or even the curative and preventive programs.

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