# Real-Time Biosurveillance Pilot in India and Sri Lanka

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## ABSTRACT

The latter parts of 2007 and early months of 2008 witnessed an alarming number of deaths due to a Leptospriosis outbreak in Sri Lanka [Agampodi et al, 2008]. This disease presents with flu like symptoms, and it is not easy to identify because other more common diseases with similar symptoms tend to emerge naturally during the monsoon seasons. The scattered number of patient complaints went unnoticed, during the rainy season, until a few deaths were reported by individual hospitals. An unusual number of flu-like symptoms concentrated in particular geographic areas (North Central and North Western Province in Sri Lanka) could have signalled the epidemiologists of an abnormal event. The present day paper-based disease surveillance and notification systems in Sri Lanka and India [Prashant and Waidyanatha, 2009], confined to a set of notifiable diseases, often require 15-30 days to communicate data and for the central Epidemiology Unit to process it. This latency does not allow for timely detection of disease outbreaks, and it limits the ability of the health system to effectively respond and mitigate their consequences. The Real-Time Biosurveillance Program (RTBP) is a pilot aiming to introduce modern technology to health departments in Tamil Nadu, India, and Sri Lanka to complement the existing disease surveillance and notification systems. The processes involve digitizing all clinical health records and analysing them in near real-time to detect unusual events to forewarn health workers before the diseases reach epidemic states. Health records from health facilities, namely the patient case disease, syndrome, and demographic information, are collected through the m-HealthSurvey mobile phone application [Kannan and Sheebha, 2009] and fed in to the T-Cube Web Interface [Ray et al, 2008], which is a browser based software tool that uses the T-Cube data structure for fast retrieval and display of large scale multivariate time series and spatial information. Interface allows the user to execute complex queries quickly and to run various types of comprehensive statistical tests on the loaded data [Sabhnani et al, 2005, Dubrawski et al, 2007]. The Sahana Messaging/Alerting Module is used to disseminate detected adverse events to targeted health officials and health workers. The Sahana Alerting module adopts the global content standard: Common Alerting Protocol (CAP) for structuring the messages that are transported via SMS, Email, and Web [Gow and Waidyanatha, 2009]. Evaluation of the RTBP

involves a replication study and parallel cohort study. This paper discusses the technologies used in the pilot and the initial findings in relation to usability of the system. The RTBP research is made possible through a grant received from the International Development Research Centre of Canada (105130).

## INTRODUCTION

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 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 et al, 2004]. Hence, there are three main components that the RTBP researches are investigating: 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).

RTBP provides the ability to detect and monitor a wide variety of health events, involving multiple kinds of diseases, including communicable and non-communicable, as well as reportable and non-reportable ones, following WHO's general recommendations for disease surveillance systems [WHO, 2004].

## RESEARCH DESIGN

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 and Ravindra, 2008]. In that respect, this section discusses the information flow that completes a cycle (steps 1 – 8, Figure 1) where information provided by health workers is processed and resulting decisions are communicated back to the health workers.

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.

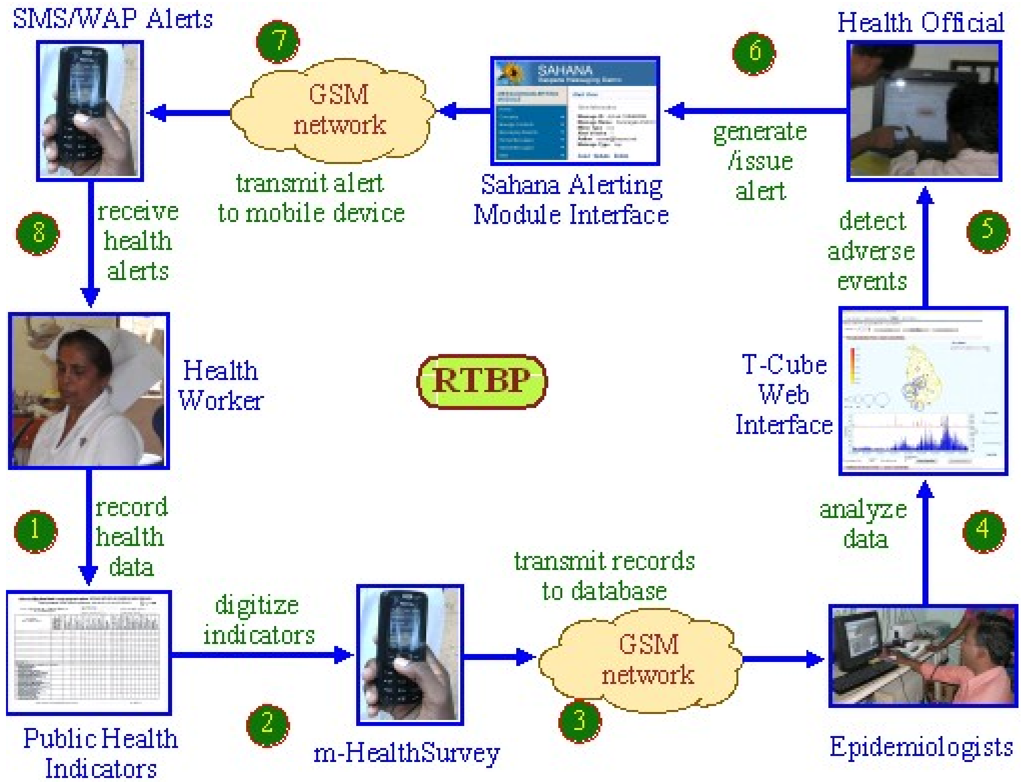


*Figure 1: RTBP actors, technologies, processes and information flow*

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.

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

Step 6 - Events of interest that require intervention and prevention or are worthy of notifying are disseminated to targeted health workers, in the form of a CAP message, through the Sahana Alerting Module, by the authorized health officials.

Step 7 – A toned 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 received alert message, the health workers, if necessary, activate relevant response plans.

## TECHOLOGIES

### *m-HealthSurvey mobile application*

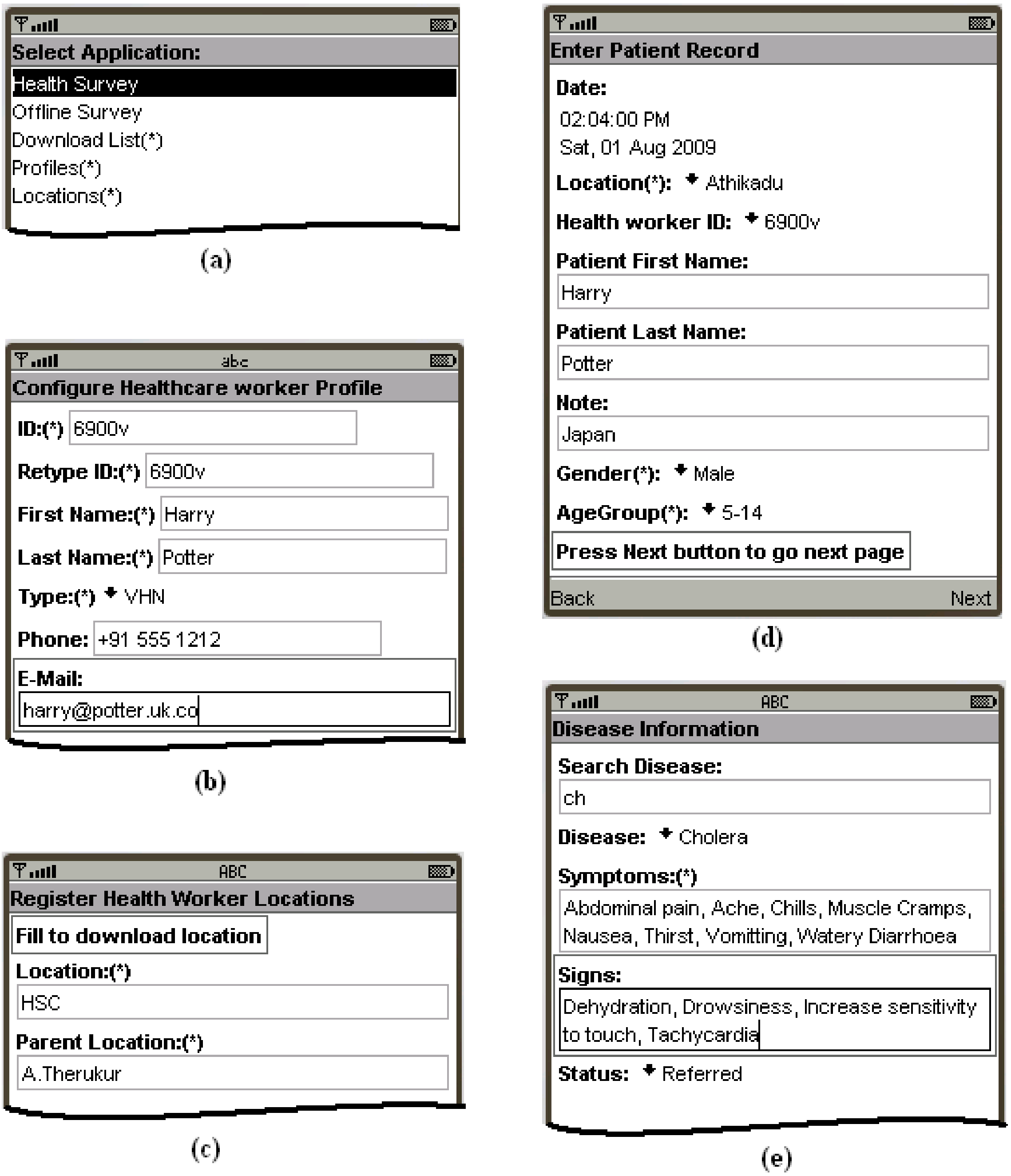


*Figure 2: m-HealthSurvey Screens (a) main menu (b) profile (c) location (d) patient record page 1 (e) patient record page 2*

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, 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 to reflect the changes in the global database. Thereafter, the user must configure the application with their preferences such as their profile, Figure 2(b), and working locations, Figure 2(c). m-HealthSurvey allows for multiple profiles permitting for more than one health worker to share the same mobile phone. After installation and configuration the user is ready to begin sending data through the *health survey* form (Figure 2(d) and 2(e)). For confidentiality, the project's initial design had not incorporated the patient's name; however, the Tamil Nadu health department 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.

### *Auton Lab T-Cube Web Interface*

T-Cube Web Interface (TCWI) is a generic tool to visualize and manipulate large scale multivariate temporal and spatio-temporal datasets commonly encountered in public health applications [Ray et al, 2008]. The interface allows the user to execute complex queries quickly and to run various types of statistical tests on the loaded data. Upon uploading the working dataset, the user can manipulate and visualize data through the Time Series, Map, and Pivot Table panels.

The user may choose to apply one of the available statistical modelling and anomaly detection techniques. The list of choices includes moving average, moving sum, cumulative-sum, temporal scan, change scan, linear trend, peak analysis and range analysis. The users can interactively manipulate, navigate, summarize and visualize data at interactive speeds. That supports focused investigations, drill-downs as well as summarizing and reporting operations. The users may choose to simply execute a Massive Screening procedure, which performs an automatic and comprehensive search for anomalous patterns across large number of queries spanning multiple dimensions of data. This function could be invoked interactively by the user, or it could be scheduled to execute periodically to generate a set of alerts. The alerts are sorted according to statistical significance of the corresponding anomalies found in data, and they can be interactively reviewed by the Epidemiologists for the factual confirmation of their practical importance. TCWI supports these efforts by allowing focusing attention on the most surprising patterns in current data and by providing the ability to quickly drill down or roll up the data for further explanations.

The core of the TCWI Massive Screening procedure is the Temporal Scan bi-variate anomaly detection algorithm [Dubrawski, 2009]. It leverages the efficiency of the T-Cube data structure to perform a massive number of tests of statistical hypotheses in order to find the most significantly anomalous patterns in current data. The TCWI also implements Multivariate Bayesian Spatial Scan algorithm [Neill and Cooper, 2009], that complements the analyses by testing the spatial as well as temporal correlations between health events. This algorithm computes the overall probability of a disease outbreak anywhere in the scope of data selected by the user, separately for each day within that scope. The national score for the current day is reported in the upper right corner of the map display window (Figure 3).

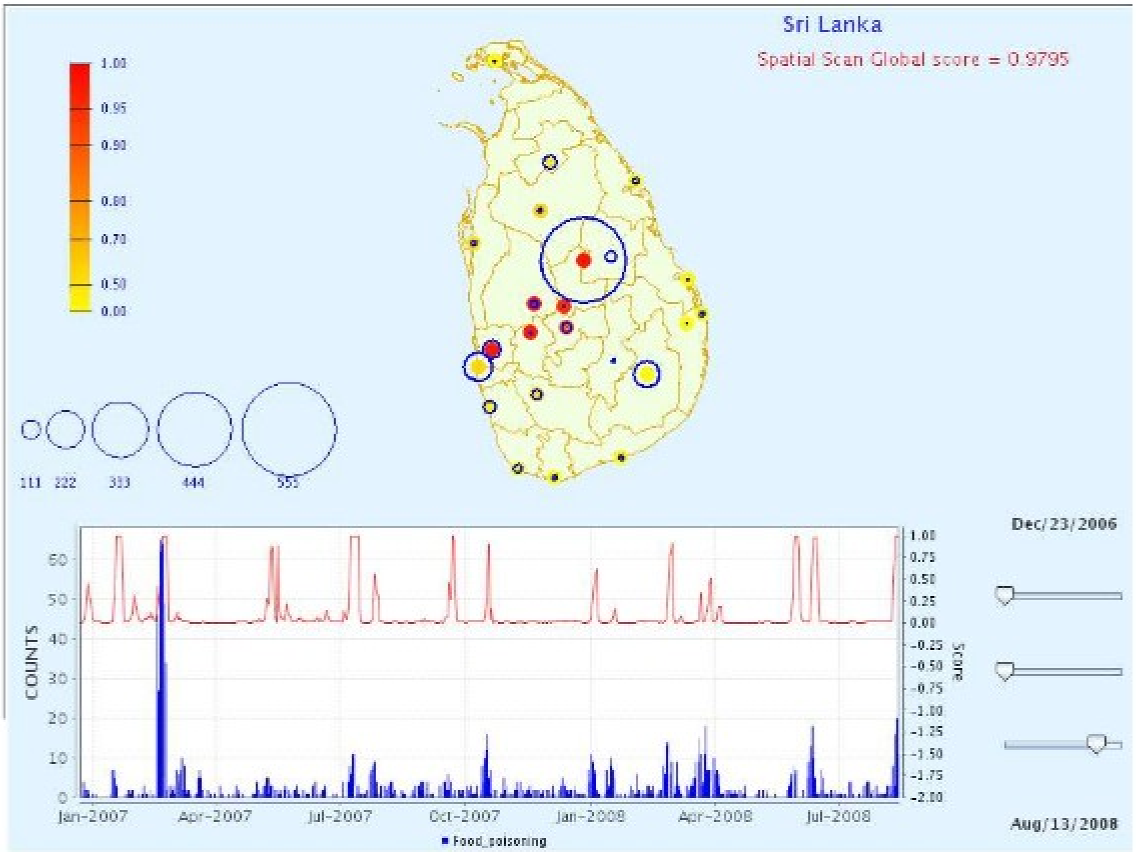


*Figure 3: T-Cube Spatio-Temporal visualization Map interface*

Figure 3 shows an example detection of a potential outbreak of food poisoning. The spatial and temporal distributions of corresponding recorded disease cases are shown in blue. The history of the estimated probability of the food poisoning occurring on a given day anywhere in the nation is depicted with the red line plot. Massive screening automatically identifies the periods of time of abnormally high frequency of cases of food poisoning, relative to cases of other diseases reported nationally. Spatial distribution of probabilities of the food poisoning outbreak computed for separate regions of Sri Lanka for the current day is depicted with filled circles coloured according to the value of the estimated probability. In this example, a central East-West swath of the country seems to be primarily affected by this disease. Figure 3 shows a global score of 0.9795 (i.e. almost a 98% chance) for food poisoning event on August 13th, 2008. This event was later identified as an actual food poisoning outbreak in Kurunegala District. When prompted by the system to the new discoveries, the analysts can further drill into the data by narrowing their filters or selecting various additional modelling techniques to confirm the outbreak.

TCWI also provides computationally efficient, interactive data summarizing capability. Multidimensional data of counts of events (such as the numbers of reported disease cases) can be aggregated into a multi-way matrix view - a pivot table. Multiple attributes can be selected to denote rows and columns of the table by dragging the corresponding attribute names from the attributes list. Once a table is created and automatically filled with values, the user can click on a cell to view the corresponding time series graph, or a pie chart depicting the frequency distribution of the underlying data.

### *Sahana Alerting Module*

The RTBP Alerting and Notification Guide is based on the US Centre for Disease Control's Public Health Information Network (PHIN) Communication and Alerting Guide (PCA). The PCA Guide has been identified as useful model on which to base the RTBP Guide because it addresses the problem of inter-jurisdictional alerting, provides a comprehensive set of alerting attributes using Common Alerting Protocol (CAP) and Emergency Data Exchange Language (EDXL). RTBP will incorporate CAP as data interchange standards for use in the research in order to serve the primary objective of the project but also to take into account other objectives related to system growth and regional interoperability.

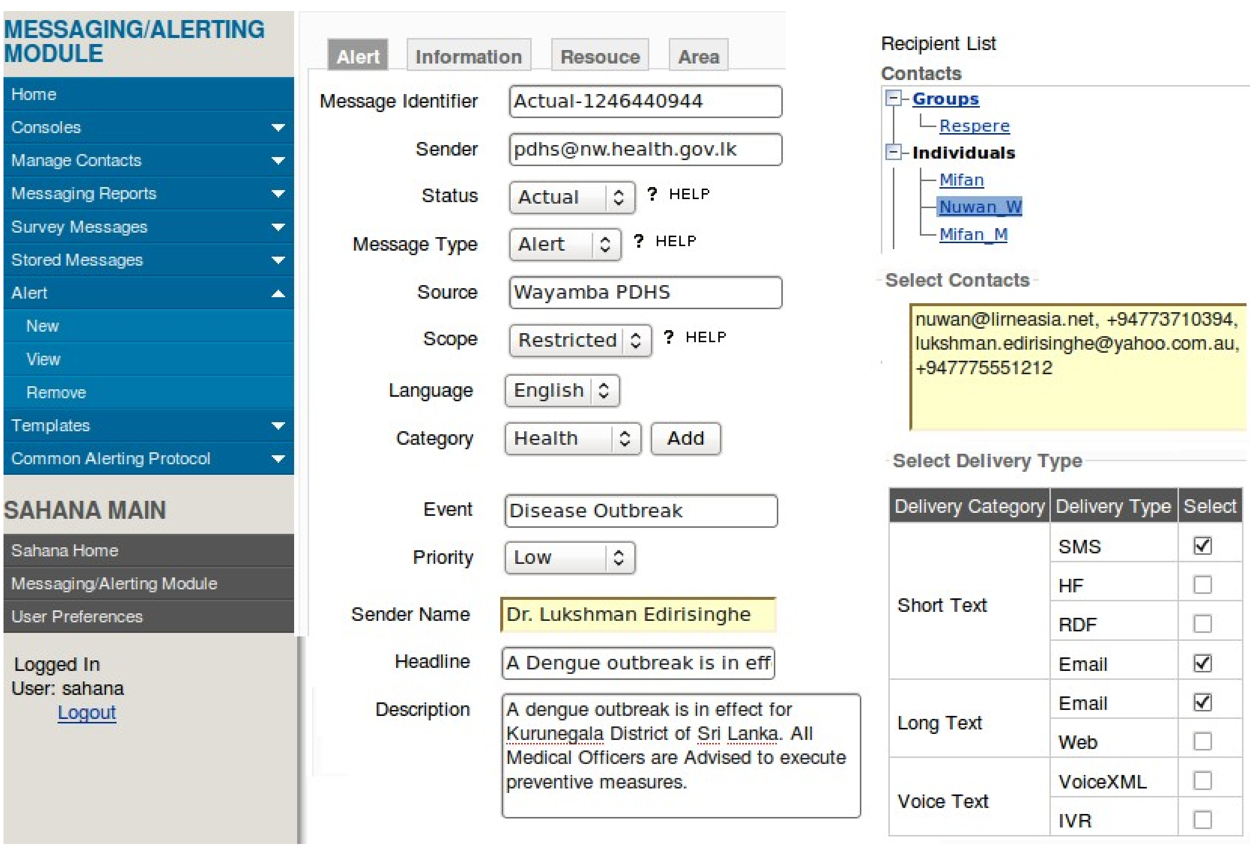


*Figure 4: Browser interface of the Sahana alert generation screens*

The Messaging/Alerting Module is a Sahana Module that is used for the sending and receiving of messages and/or alerts. The module allows for the generic sending and receiving of messages as Short Messages via the Short Messaging Service (SMS), sending messages as Email, conducting SMS based surveys and sending CAP alerts. The CAP alerting section, which falls under the scope of the RTBP is accessed via the Alert and Templates subsections (Figure 4). The system allows users to create CAP templates and store them in the system. These can then be used when creating CAP messages, which allows the message to be populated based on the relevant template. The template can then be used to pre-populate fields when creating a new alert.

Figure 4 shows an example of an alert generated to notify a dengue outbreak. Each message carries a unique identifier, a set of attributes that identifies the source and sender for audits. The scope is set as restricted meaning the message is for those targeted recipients only. Category is naturally set to Health with the event described as an "out break". Priority defines the response actions that should be taken by the receiving health workers or health officials. If the priority was set to "urgent" then recipients may be required to take prompt action; while a "low" priority may mean being vigilant and observe the situation. The description section contains a full synopsis of the alert. Once the attributes are populated the sender can select or type in the list of recipients in the Contacts section (upper right corner in Figure 4). Thereafter, select the delivery types (or transport methods), i.e. email, SMS, web, for the message to be disseminated to the prescribed recipients via those channels.

## EVALUATION METHOD

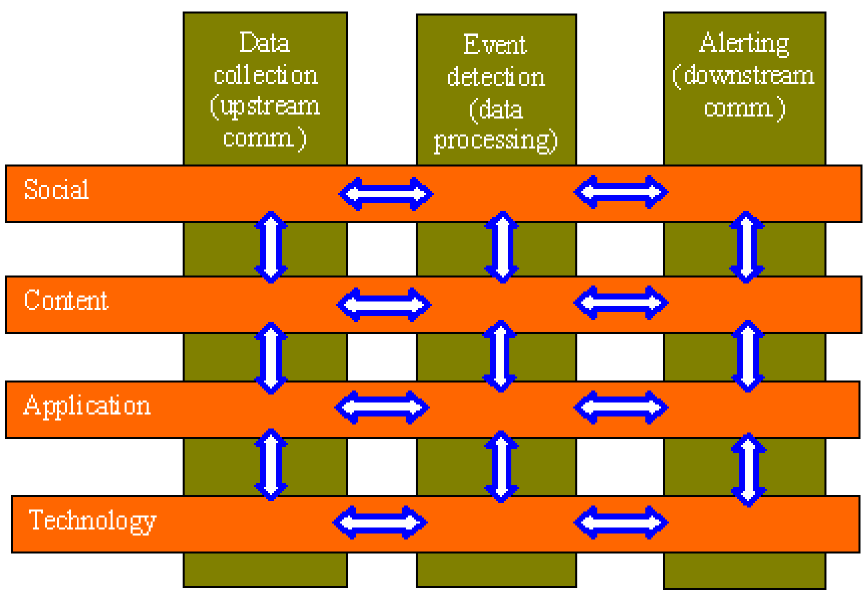


*Figure 5: Vertical components of the RTBP communication structure and horizontal layers of each component with arrows depicting the interoperability*

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 5. The vertical segments are, further, horizontally partitioned in to social, content, application, and technology layers (Figure 5).

RTBP adopts a selected set of the evaluation methods from the following literature - Ammenwerth et al, 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, 2003, have proposed biosurveillance system evaluation methods. Anderson and Aydin (2005) describe methods and key aspects of qualitatively evaluating the organizational impact of introducing ICTs in Healthcare. Friedman and Wyatt (2006) introduce subjective and objective quantitative and qualitative methods for evaluating bioinformatics systems.

As part of the cohort study, the project will execute simulations to evaluate the reliability and effectiveness of each of the verticals; in other instances will take the present system as a basis to assess the proposed system. The replication study would involve injecting data from the past and evaluating the systems performance with respect to known events in the past.

## DISCUSSION

### *m-HealthSurvey*

None of the health workers, with ten years or more field experience in rural India, age ranging from 30 – 55 years, had ever used SMS and were only conformable with using voice. RTBP's m-HealthSurvey J2ME application is their first experiences using mobile key pad for entering text. A certification exercise on the users ability to install/configure the mobile application, submit data in a timely manner, and understand the standard operating procedures revealed young Health Workers in Sri Lanka were far more comfortable with using the m-HealthSurvey and understanding the processes. In Sri Lanka 14 of the 16 and in India 23 of the 25 health workers participated in the exercise. While 12 of the young health workers in Sri Lanka scored over 70% only four of the health workers in India were able to achieve the same.

One reason to minimize the amount typing and allow for selection from pre-populated lists is to minimize on the data entry time and spelling errors. However, the health workers in India were more comfortable recording the data on paper and later submitting them at the end of the day, which is not quite real-time submission of data the project anticipated. Similarly, in Sri Lanka the health workers would submit the data in the afternoon were they recover the data from the clinical chits produced in the morning.

Each day the databases records approximately 800 records from Sri Lanka and 500 records from India. These records come from 17 health facilities in Sri Lanka and 29 health facilities from

India. The number of misspelled and erroneous records account for 12% in Sri Lanka and 17% in India. This is mainly due to the absence of pre-populated disease-syndrome data in the mobile phone memory and health workers typing values. The data received varies between British spelling and US spelling, e.g. “diarrhea” versus “diarrhoea”. The project was unable to find a freely available database in the public domain that would provide a complete comprehensive disease-syndrome list. These inconsistencies in the data lead towards false predictions in the analysis.

***T-Cube Web Interface***

Statistical surveillance analyses rely on the robustness of data received from the health workers through the m-HealthSurvey. The inconsistencies in data introduce noise which in turn can decrease event detection rates and increase rates of false positive alerts. To overcome the effect of such noise, the project has defined a set of high priority diseases, symptoms, and signs. Other diseases, symptoms, and signs are categorized commonly as “other”. The drawback of this approach, although it does reduce the noise, is that this method does not capitalize on the full capabilities of the T-Cube-based analytics to find correlations in data when it is clumped in a low-resolution “other” category.

The present systems in India and Sri Lanka reports high priority cases such as dengue and malaria on daily basis through telephone calls. The calls are made at the end of the peak patient care period which on a typical day occurs between 8am and 1pm. Medical Office of Health (MOH) departments in Sri Lanka and Integrated Disease Surveillance Program (IDSP) of the DDHS in India consolidate this information on a weekly basis using spreadsheets. The paper-based, manual consolidation method does not provide the real-time surveillance ability, and most importantly, it does not present the data in a navigable and searchable spatio-temporal format as does the TCWI. The computational efficiencies offered by the T-Cube data structure enable health surveillance officials and epidemiologists to quickly see the data visualized spatially on a map and temporally on time series plots. They can monitor evolution of disease in spatio-temporal fashion, either at a high-level of regional or national aggregation, or drilling down as needed to even single cases of diseases like malaria or dengue fever. Accessing the information collected throughout jurisdiction of their particular MOH or DDHS, but also throughout the neighbouring jurisdictions or over an entire region, will provide better situational awareness and allow more effective responses.

An important requirement for TCWI in the RTBP project is to achieve high level of intuitiveness of its operation, even by users without a lot of specialized training in statistical disease surveillance. Not all health officials in rural India and Sri Lanka are quite familiar with the advanced statistical methods implemented in TCWI. Therefore, the full potential of TCWI may not be exploited initially. RTBP is implementing an iterative process through which the technical solutions of the user interface, technical documentation, and training regime, will converge to an end state of feasible level of practical capitalization on the potential of the implemented technology.

The studies of utility also involve designing the procedures for scheduling TCWI event detection algorithms to execute automatically in order to periodically generate a set of alerts which then can be communicated to the appropriate recipients. These alerts will include a list of current findings, their time spans, affected locations, and probabilities or significance scores, and they will be disseminated to targeted officials via SMS and Email. These officials upon receiving the alerts would use TCWI to further verify the validity of these potentially adverse events, and to make decisions regarding any necessary response activity required to mitigate the situation.

In order to validate the accuracy of the implemented statistical algorithms, RTBP team has extracted publicly available Weekly Epidemiological Reports published by Sri Lanka Epidemiology Unit, and used it to synthesize data of the shape and form identical to that being collected through m-HealthSurvey. Analysing such data with TCWI, we have found reliable signals pertaining to leptospirosis and dengue fever events as early as two months ahead of time of their detection with the existing processes. Data is currently being collected in India to execute a similar replication study and its results will be disseminated in the near future.

***Sahana Alerting Module***

Researchers came to learn that the IDSP of DDHS in Sivagangain District, Tamil Nadu, India was already using a web portal – www.way2sms.com – to send SMS text messages to schedule emergency meetings with Medical Officers and other health officials in their jurisdiction. However, this portal does not allow for storing pre-formatted message templates of recipient groups. Such a method is not used in Sri Lanka but they use voice and in some instance need to make a physical visit to convey the invitation. In most cases, when the rapid response teams need to be conveyed to investigate a high priority infectious disease case they revert to a phone call (i.e. voice). Current practices are convenient for low volume alerting; however, is inefficient for broadcasting to larger sets of health workers or health officials during a crisis.

Health officials see the benefits in the Sahana Alerting Module, which is structured to maintain recipient groups and reusable templates. This would increase the efficiencies in disseminating situational reports to targeted health workers and health officials. The project was able to integrate www.mytoday.com sms portable to send unlimited number of SMS text for free. The SMS text is disseminated through a GSM Modem that is connected to the Sahana server, which costs about Rupees 0.50 per text message.

Interviews with health workers in India and Sri Lanka indicates that health workers do not directly receive any situational reports and they get their informations predominantly through the local Television channels, Radio stations, or News papers, which they will come to know if they tune in to those media. In the case of Sri Lanka word-of-mouth was another popular source for learning of health risk news. Whereas the SMS can be directly sent to health workers, all of whom have a mobile phone, and are certain to receive the health risk information and much earlier than through media channels.

## CONCLUSION

The health departments and health workers involved in the RTBP pilot see the benefits in the m-HealthSurvey for real-time data collection, T-Cube Web Interface for near-real-time outbreak detection, and Sahana Alerting Module for real-time health risk information dissemination. Preliminary lessons to date indicate the need for more robust mobile application for data collection with complete standardized content in disease-syndrome for reduction of noise and increase of reliability in the datasets. More rigorous capacity building and frequent use is required for health officials to take advantage of the full potential of TCWI. Further exercises need to be carried out with the Sahana Alerting Module to understand its shortcomings. Given that the system has been in preliminary use for less than six months, it is anticipated that the usability issues will subside in time to come.

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**AUTHORS' BIO AND PHOTOS**

**Nuwan Waidyanatha** is a Senior Researcher with LIRNEasia and is the Project Director of the research - "Evaluating a Real-Time Biosurveillance Program". His expertise are in ICT system design and actionable research working collaboratively with multiple national and international stakeholders. He applies the academic and industrial experience in providing practical solutions for developing nations. Present research is in developing early warning systems and information exchange platforms for emergency communication. He is an advocate of Free and Open Source Software and is a member of the Project Management Committee of the Sahana open source community. His tertiary education is in Operations Research, Mathematics and Computer Engineering.

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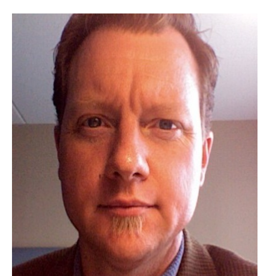
**Pubudini Weerakoon** is currently employed with Sri Lanka's largest NGO – Lanka Jathika Sarvodaya Shramadana Society – and is the research assistant for the Sri Lankan portion of the pilot study: "Evaluating a real-time biosurveillance system". Her interests are in environmental governance and civil society. In 2008, she received her a Bachelors degree in Bioscience from the University of Kelaniya, Sri Lanka; where the research in relation to environmental hazards involved studying the effects of textile mill effluents on Macro benthic faunal community in
Weras ganga river connected to the Bolgoda North Lake.



**Gordon Gow** is an Associate Professor in Communication and Technology at the University of Alberta. His teaching and research examines the impact of new communication technology on public health and safety. His areas of expertise include mobile and wireless communications, telecommunications policy, Internet and social media. Currently, he is principle investigator on a multi-year SSHRC-funded project (Standard Research Grant) to examine campus alerting in Canada. Dr. Gow is also director of the MARS micro-lab (Mobile Applications for Research Support) at the University of Alberta. The MARS lab provides support for projects investigating the use of the mobile communication devices in support of scholarly and community-based social science research.

**Maheshkumar Sabhnani** is a PhD student at the Machine Learning department, Carnegie Mellon University. His research interests include finding complex spatio-temporal anomalous patterns in any transactional data sets with categorical attributes. For syndromic surveillance, the primary focus is to propose practical algorithms to detect disease outbreaks both effectively and timely.

**Artur Dubrawski** is interested in intelligent systems that work, are useful, and make economic sense, and in finding ways to build and deploy them. His work is driven by real-world applications in the areas of public health, food safety, nuclear safety and equipment management. It involves researching new machine learning algorithms and data structures to facilitate probabilistic modelling, predictive analysis, interactive exploration, and understanding of data. Dr. Dubrawski directs the Auton Lab at Carnegie Mellon University, is a faculty at the CMU Robotics Institute and Heinz College, and an adjunct faculty at the University of Pittsburgh Department of Biomedical Informatics.