A Reference Architecture for Developing Resource-Limited Disease Surveillance Systems

Agung Fatwanto[1]

[1]Informatics Department, UIN Sunan Kalijaga, Jl. Marsda Adisucipto Yogyakarta Indonesia 55281
agung.fatwanto@uin-suka.ac.id

Abstract- **In recent years, several countries have developed and implemented disease surveillance systems. These systems, eventhough having relatively similar functions, are adopting different approaches. Based on a preliminary study, an effective strategy for developing a disease surveillance system was proposed. This paper proposes a reference architecture for building a disease surveillance system based on the medical and technological perspective in the context of resource-limited environment.**

I. INTRODUCTION

Anticipating communicable diseases is really challenging especialy for the health authorities. Providing proper responses quickly is also another difficult task. With the possibilities of biological wars and terrors where infectious diseases are used as the lethal weapons in some war fields by contradictory camps are even exacerbating those already difficult work.

An outbreak can now spread rapidly due to the emergence of mass and rapid transportation. Infected people travel throughout region and country in which they can bring and spread diseases to and from the visited places. The challenge in facing infectious and communicable diseases hence become more futile.

A lot of governmental health agencies have been realizing this challenge. They have been trying all efforts to anticipate the worst situation. They have considered that any problems related to the public health are actually a potential threat to their national security. Several initiatives on the development of disease surveillance systems therefore have been started.

Due to the established infrastructure and high human-resource readiness level, developed countries will have insignificant bariers in implementing disease surveilance systems. Developing and under-developed countries, on the other hand, have relatively limited infrastructure and lower human-resource readiness level hence will be struggling in implementing disease surveilance systems. In this kind of condition, the implementation of disease surveilance systems requires several considerations.

The aim of this paper is to propose a reference architecture for developing disease surveillance systems particularly for resource-limited context. The proposal for the reference architecture was considering the technological, data gathering, and medical perspective.

This paper will be structured as follow. Section 2 reviews the literature on disease and epidemic outbreak tracking systems from technological, data gathering, and medical perspective. Section 3 discusses a reference architecture for developing and implementing diseases surveillance systems in resource-limited context. Finally, section 4 summarizes this paper.

II. REVIEW ON DISEASE SURVEILLANCE SYSTEMS

Health informatics applications (which sometimes can also be called as electronic health or eHealth in short) have been developed and implemented in some parts of the world. The applications serve for several purposes, namely: remote data collection, remote monitoring, diagnostic and treatment support, disease and epidemic outbreak tracking, education and awareness, and also communication and training for healthcare workers [1].

Diseases surveillance systems, among others, are important due to the increasing threats of the communicable and infectious diseases which may spread quickly over different regions. The threats obviously threaten public health and national security. Disease surveillance system is a type of eHealth application that is developed to monitor any disease and epidemic outbreak which might occur within a particular region at particular time. This type of application is therefore important for minimizing the threats and anticipating the worst scenario. The technology is implemented to assist the identification of outbreak and hence could better allocating resources to the places with greatest need.

A description of the currently available disease and epidemic outbreak tracking systems especially in terms of their development and implementation context is thus required. This study had try to review a number of health applications and focused on the applications developed and implemented for resource limited context which, in most cases, heavily relied on mobile communication devices.

Based on technological point of view, disease surveillance systems can be deployed either manually or automatically (meaning electronically). Among the manual deployments are: paper-based and communication tool-based surveillance.

Paper-based technique is the oldest way of conducting disease surveillance. This technique relies on paper-based reporting from the lowest-level officers/paramedics send over their higher rank colleagues to be compiled and analyzed further. This process is apparently slow (time consuming) and error-prone since it pretty much involves human tasks. However, this technique requires minimal investment and very suitable for places with strongly limited-resources.

The communication tool-based surveillance is an extension to the paper-based technique, in which it involves the use of communication tool such as telephones, facsimiles, radio communication devices, telegraphs, emails, etc for reporting purpose. Although this technique already uses technology, however there still no automation in compiling and analyzing the report. This type of technique is actually similar as the paper-based technique but with making use of the available communication tools without further exploitation on process automation.

The main difference between manual and automatic (electronic) disease surveillance is in the way on handling report compilation and analysis. Manual surveillance requires report dataset to be compiled and analyzed by human. Meanwhile, automatic (electronic) surveillance utilizes technology for the compilation and analysis of report dataset. Hence, automatic (electronic) surveillance systems can result in faster and more accurate report than their manual counterparts due to the use of technology.

There are two types of technology used as the building platform for automatic (electronic) disease surveillance systems: desktop-based and mobile-based system. Although they implement different technology, both rely on web-based platform.

Desktop-based systems normally developed and implemented in a non resource limited context where the environment into which the systems are going to be deployed have a certain readiness level. At least, there are two prerequisites the environment has to provide in order for a desktop-based system can be deployed: infrastructure and human-resource readiness. Infrastructure readiness means that the environment into which the systems will be deployed should have particular instruments where the desktop application can be installed and executed and also sufficient internet connection coverage where the data can be transmitted from all data entry point to the datacenter and vice versa. The instruments can be in the form of PC desktop, laptop, or netbook with sufficient component specifications hence the application can run on top of the particular hardware. Internet connection must be widely available and covering most of the regions where the system is deployed. The connection should also have enough bandwidth hence the data transmission can run over it. Human-resource readiness means that the environment should have person with the capabilities to operate and maintain the system.

Considering the implementation context for desktop-based surveillance systems, thus most of the places which developed and implemented this type of system are those of developed countries (such as European and North American). Only a few developing countries that already deployed this type of

system, such as Indonesia with EWORS (Early Warning Outbreak and Response Systems) [2] and Peru (Alerta Disamar) [3].

Mobile-based systems normally developed and implemented in a resource-limited context where the environment into which the system are going to be deployed does not have a certain level of infrastructure readiness, especially in regard to the internet connection coverage. Most developing and under-developed countries, especially those with vast areas or uncentralistic settlement pattern, tend to develop and implement mobile-based system. There are at least two advantages of using the mobile-based system for deploying the disease surveillance system. First, data transmission can be arranged over mobile phone network that even though with a relatively limited bandwidth but have wide coverage. Second, the availability of the instruments (especially that for data entry) which is cheaper and widely available. Another advantage of using mobile phones as the tool for data entry is that most people are getting used to mobile phones hence minimizing the adoption efforts, learning time, and training. It helps the responsible person in mastering the application thus increasing human-resource readiness level.

As the examples of mobile-based disease surveillance systems are: AESSIMS that has been deployed in Brazil, EpiSurveyor which has been successfully deployed in Kenya and other places, and InSTEDD that has been deployed in South East Asia [1].

Table I summarizes the analysis of disease surveillance systems from the technological perspective.

TABLE I
A CLASSIFICATION OF DISEASE SURVEILLANCE SYSTEM FROM TECHNOLOGICAL PERSPECTIVE

No.	Type	Advantage	Disadvantage
1	Manual		
	Paper-based systems	Lowest requirements and highest infrastructure and human resource readiness level	Very slow (time consuming) reporting and error-prone (full human involvement)
	Communication tool-based systems	Low requirements of infrastructure and human resource readiness	No realtime reporting and still have human-error potential
2	Automatic		
	Desktop-based systems	Realtime reporting (with full reporting features) and less human error	Requires highest infrastructure and human resource readiness level
	Mobile-based systems	Realtime reporting (with limited features) and less human error	Requires sufficient mobile network coverage for the serviced region

From the data gathering perspective, data might be gathered using two types of approach, namely: structured and unstructured.

Structured data gathering is a kind of approach where data are collected from the authoritative parties such as paramedics, health authorities, etc. Since the data are gathered by design, the database format can be structured accordingly. However,

this type of data gathering implement passive mode, meaning that the system collect data whenever an event occur and reported to the authority. This kind of data gathering can be deployed for both resource-limited and non resource-limited context.

Unstructured data gathering, on the contrary, collect data from several sources both from authoritative and non-authoritative references. Since the data are collected from various sources, the database format cannot be structured according to the designers' need. This type of data gathering implement active mode, meaning that the system actively collect data anytime it requires from various sources such as mass media, social networking, blog, and media having user generated content. This kind of data gathering can normally be deployed only for non resource-limited context.

Table II summarizes the analysis of disease surveillance systems from the data gathering perspective.

TABLE II
A CLASSIFICATION OF DISEASE SURVEILLANCE SYSTEM FROM DATA GATHERING PERSPECTIVE

No.	Type	Advantage	Disadvantage
1	Structured	Provide accurate report	Requires authoritative approval for data entry (slow)
2	Unstructured	Can collect data actively (fast)	Less accurate report

From the medical science perspective, disease surveillance systems can be classified into two categories based on the way how the data are gathered, namely: traditional (diagnostic) and syndromic (pre-diagnostic) surveillance.

The traditional (diagnostic) surveillance is a type of disease surveillance where the data that are going to be entered into the system is obtained from the medical authorities (doctors, team of paramedics, etc.) diagnostic results. This type of surveillance provides an accurate report since the gathered data is based on very mature result of paramedic diagnostics which in some cases are strengthened with the laboratory data. However, this kind of surveillance takes a lot of time in waiting the diagnostic result and requires medical authorities' approval for data gathering.

In contrast to the traditional (diagnostic) surveillance, the syndromic (pre-diagnostic or symptom-based) surveillance does not require diagnostic results from the medical authorities. Instead, it gathers the data based on the syndrome or symptom felt by the patients that are observed by the paramedics (Anamnesis). Although it does not provide report as accurate as the traditional surveillance, it offers quicker report since the data can be compiled and analyzed as soon as the patient observation has been conducted. Another advantage for this type of surveillance is that it does not require the availability of paramedics with certain level of expertise to enter the data into the system, a condition that hinders the deployment of traditional (diagnostic) surveillance for regions having limited medical expert coverage such as in developing countries.

There are several names for the syndromic surveillance, such as: symptom-based surveillance, health indicator surveillance,

prodrome surveillance, information system-based sentinel surveillance, biosurveillance, outbreak detection system, and early warning system [4]. However, these names are actually similar in terms of data gathering: syndromic (pre-diagnostic) surveillance.

Table III summarizes the analysis of disease surveillance systems from the medical perspective.

TABLE III
A CLASSIFICATION OF DISEASE SURVEILLANCE SYSTEM FROM MEDICAL PERSPECTIVE

No.	Type	Advantage	Disadvantage
1	Traditional (diagnostic) surveillance	Provide accurate report	Very slow (time consuming) reporting
2	Syndromic (pre-diagnostic) surveillance	Faster report	Less accurate report

II. A REFERENCE ARCHITECTURE FOR DEVELOPING RESOURCE-LIMITED DISEASE SURVEILLANCE SYSTEMS

The development of disease surveillance systems, both for resource-limited and non resource-limited context, can adopt a general software system development method. A number of existing software engineering literature provide abundance options for software development models. In this paper, a software system development method particularly for requirements engineering called Concern-Aware Requirements Engineering (CARE) method is adopted [5].

Using the CARE method, concerns are initially elicited from the stakeholders of the proposed system. In regard to the disease surveillance systems, stakeholders are among others the paramedics who will directly use the system and the health authorities who will use the result of this system. Concerns should also be elicited from the developers who will develop the system. Particularly for this paper, the concerns that will be used as the development consideration are mainly from the developers' perspective. Two concerns that will be highlighted in this case are: infrastructure and human-resource limitation.

By following the CARE method, these concerns will later be manifested as development goals and issues. In this case, the concerns infrastructure limitation will be manifested as a goal to "develop a mobile-based system" whereas the human-resource limitation will be manifested as a goal to "develop a syndromic (pre-diagnostic) based system". The first goal is actually has a positive contribution to the second goal in which the implementation of mobile-based system can reduce the need of high human-resource readiness level.

A mobile-based system deployment could reduce the learning time where the operators do not require intensive training to get acquainted with the hardware since most people already familiar in using mobile devices than, say, desktop PC. The decision to select mobile-based system deployment may also increasing the learning curve for the involved operators.

The decision to implement a syndromic-based surveillance system is based on the consideration of the deployment setting in a resource-limited context where the paramedics are quite limited and mostly concentrated at few places (such as big cities). Hence, the option of implementing traditional (diagnostic) surveillance cannot be accommodated in this

context. Similar as the decision from technological perspective, the decision to select syndromic-based surveillance may also increasing the learning curve for the involved operators which sometimes is not a doctor (but rather other type of paramedics such as nurses, midwives, or pharmacists).

Table IV summarizes the design decision for developing disease surveillance system for resource-limited context.

TABLE IV
THE DESIGN DECISION FOR DEVELOPING DISEASE SURVEILLANCE SYSTEM FOR
RESOURCE-LIMITED CONTEXT

Data collection	Data Gathering Type	Technology Platform
Syndromic (pre-diagnostic) surveillance	Structured	Mobile-based system

Such kind of design decision as shown in Table I can later be transformed into system architecture. A mobile-based system is actually a surveillance system in which mobile devices are utilized as the front-end side (entry point interface) from which data are entered. By considering the internet connection limitation, thus data will be transmitted over GSM or CDMA network. In a more advance environment, data transmission can be arranged over 3G, HSDPA or even LTE network.

At the back-end side, the data will be collected at the database server where all its content can be accessed using any any kind of devices owned by the health authorities (desktop PC, notebook, netbook, tablet, etc.) off course by authorized parties. Database can be accessed using desktop-based, web-based, and even mobile-based applications.

This kind of architecture makes the dissemination of information to various parties possible. Data thus can be sent to the person at every level of the institution: entry point officer through mobile-based application, health authorities at all levels through desktop-based or web-based application, and community who want to obtain the information through web-based application.

Figure I depict software system architecture for the proposed disease surveillance system for resource-limited context. This architecture can be used as the referenced model in developing and implementing disease surveillance system in which the connection medium uses mobile network (GSM or CDMA). In practices, this architecture can be manifested by maximizing the utilization of SMS gateway, GSM/CDMA data connection, etc.
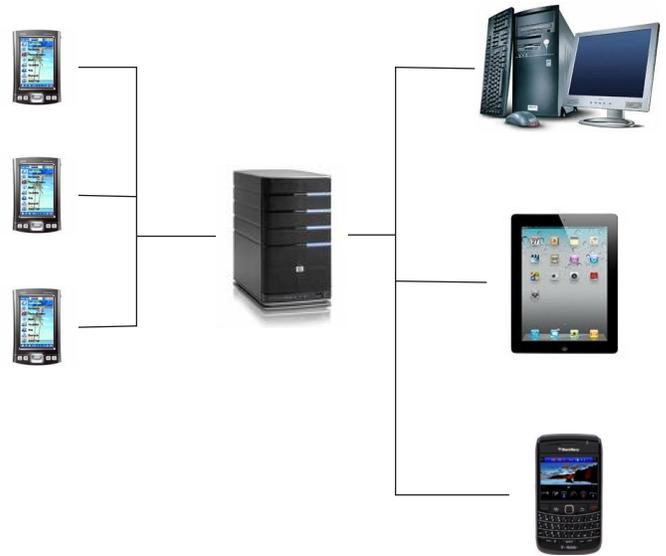

Fig. 1. A reference architecture for disease surveillance systems on a resource-limited context

IV. SUMMARY

A reference architecture for the development and implementation of disease surveillance systems particularly for resource-limited context has been proposed. The reference architecture was proposed based on three analysis perspectives: medical data collection, data gathering type, and technology platform perspective. Based on this analysis, a disease surveillance system for resource-limited context will be properly developed and implemented if following syndromic (pre-diagnostic) data collection, structured data gathering, and mobile-based platform.

This reference architecture in practices can be translated into several kind of deployment. For example, a disease surveillance system can be built consist of a database server, a number of low-end data entry terminals (for front-end operators) using short message service (SMS) application, and a set of high-end data access terminals (for back-end operators).

For the front-end side, data transmission medium from mobile devices (as the data entry terminals) to database server can use GSM or CDMA (for the worst case condition), 3G, HSDPA, or even LTE (for the advanced areas). For the back-end side, various kind of platform such as desktop-based, mobile-based, or web-based application can be use to access the database using different kinds of technology: desktop PC, tablet, mobile devices, etc. At this point, the connection medium can use internet (both public or private network) and intranet.

Since health related data are regarded as very confidential artefact, hence the security aspect of disease surveillance systems will be of primary concern for several parties. In this context, protection to the database server, access mechanism security, and access level management should be govern accordingly.

Another aspect that needs to be considered in order to increase the success factor of developing ang implementing

disease surveillance systems is the working behavior of the data entry operators (in this context is paramedics). The disesase surveillance systems will have no value if the data are not valid and not updated in realtime (or at least regularly). The consideration to the working behavior of the user (paramedic) will therefore be a key success factor for the development and implementation of disease surveillance systems. The note taking habit such as writing on the small size paper or voice-recorded note taking are samples of this behavior. These two consideration, security aspect and user's working behavior, will be the topic for the future study.

REFERENCES

[1] ---, "mHealth," *http://en.wikipedia.org/wiki/MHealth*, Last accessed November 22nd 2011.

[2] H. Siswoyo, M. Permana, R.P. Larasati, J. Farid, A. Suryadi, and E.R. Sedyaningsih, "EWORS: Using a syndromic-based surveillance tool for disease outbreak detection in Indonesia." *BMC Proceeding*, vol. 2 (Suppl. 3):S3, pp.1-5, 14 November 2008.

[3] E. Gozzer, *Alerta: Electronic Disease Surveillance for Rapid Detection of Potential Outbreak in Rural Setting.* Asia Pasific Economic Forum Industry Roindtable, 13 October 2008.

[4] K.J. Henning, "What is Syndromic Surveillance." *MMWR Supplement*, vol. 53, pp.7-11, 24 September 2004.

[5] A. Fatwanto, "A Concern-Aware Requirements Engineering Framework" *Ph.D Thesis, The Australian National University, Canberra, 2011.*