mHealth for Influenza Pandemic Surveillance in Developing Countries

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Abstract
Influenza pandemics caused millions of deaths and massive economic losses worldwide in the last century. The impact of any future pandemic is likely to be greatest in developing countries as a result of their limited surveillance and healthcare resources. eHealth facilitates the detection and reporting of potential pandemic strains by using digital data transmitted, sorted and retrieved electronically both at the local site and at a distance. The implementation of eHealth is resource costly but developing countries have limited financial and technical resources. This adversely affects access to eHealth applications. Mobile communication technologies hold great promise in improving access to and affordability of eHealth services even to the poorest areas. This paper illustrates how a mobile phone SMS-based application can be applied to mHealth, potentially facilitating influenza pandemic surveillance in developing countries.

Keywords-Public Health Surveillance, mHealth, Pandemic, Developing Countries

1. Introduction

Influenza pandemics can occur with the appearance of a new influenza virus against which none of the population has any immunity [1]. During the last century, several influenza pandemics caused millions of deaths, social disruption and profound economic losses worldwide [1]. With the increase in global transport and communications, as well as urbanization and overcrowded conditions, a novel influenza strain is likely to spread quickly around the world. The impact of a future pandemic is likely to be greater in developing countries as a result of their limited surveillance and healthcare resources [1][2]. Developing countries are the nations which often have abundant natural resources but lack the capital and entrepreneurial and technical skills required to develop them [3]. The average income per head and the standard of living in these countries is therefore far below that of the industrial nations [3].

eHealth, as an application of information and communication technologies (ICT) across the whole range of functions that affect health [4], facilitates the detection and reporting of the potential pandemic strain by using of digital data transmitted, sorted and retrieved electronically both at the local site and at a distance. Amongst types of ICT infrastructure, e.g. hardware, software and network, network has drawn the most attention in eHealth initiatives and implementations [5]. As eHealth is often information-intensive, it requires access to lines with considerable capacity of transmitting large amounts of data [6]. As such, limited web access and slow Internet speed are a major concern, particularly in developing countries, where high-speed internet access is not widely available [5]. However, while developing countries may lack high-speed Internet access, affordable mobile phone service is widely available and used [7]. For this reason, mobile communication technologies hold great promise in improving access to and affordability of eHealth services even to the poorest areas [5][7].

Inspired by the growth of mobile communication technologies, global health policy-makers and providers are strengthening mHealth as a new weapon to fight against global health crisis for connecting the unconnected [8]. mHealth (a subset of eHealth) aims to achieve the objectives of eHealth using of mobile wireless devices, such as cell phones and PDAs. Mobile communications have all the potential to radically transform the health care services –“even in
some of the most remote and resource poor environments [9].”

The objective of this paper is to illustrate how a simple, inexpensive mobile phone SMS-based application can be applied to mHealth, potentially facilitating influenza pandemic surveillance in developing countries. The rest of the paper is organised as follows: Section 2 discusses background information and the motivation to apply mHealth in public health surveillance; Section 3 discusses the potential use of mHealth in developing countries; Section 4 describes the features of an open source application called FrontlineSMS and illustrates how it can be applied for a pandemic response; Section 5 concludes with a summary of our study, current limitations and future work.

2. Background

Influenza A and B are two of the three types of influenza viruses associated with annual outbreaks and epidemics of influenza. Only the influenza A virus can cause pandemics [1]. These pandemics are the result of minor changes in the influenza viruses that enable them to evade the immunity people have developed after either previous infections with the viruses or in response to vaccinations. When the virus has the capacity to spread from person to person, a pandemic can occur [1]. The 2009 flu outbreak, known as "swine flu", is due to a new strain of influenza A virus subtype H1N1 that contains genes most closely related to swine influenza [10][11]. The new strain was initially described as apparent reassortment of at least four strains of influenza A virus subtype H1N1, including one strain endemic in humans, one endemic in birds, and two endemic in swine [12]. This strain can be transmitted from human to human [13], and causes the normal symptoms of influenza [14]. On June 11, 2009 the WHO declared swine flu a global pandemic, the first in 41 years [15]. Over 180,000 cases and 1799 deaths in 177 countries have been attributed to swine flu, and the WHO expects these numbers to increase before a suitable vaccine is developed [15].

In order to better fit surveillance requirements to pandemic phases, it was suggested that the WHO phases are renamed as follows [1],

- Inter-pandemic: Routine influenza pattern in humans and animals.
- Pre-pandemic: 1. Influenza strain with pandemic potential identified in birds or animals. 2. Influenza strain with pandemic potential identified in humans. 3. Human-to-human transmission of the influenza strain with pandemic potential confirmed.
- Pandemic: Multi-country or regional outbreaks of pandemic influenza strain with efficient human-to-human transmission.

During the pre-pandemic phase, the priorities for human influenza surveillance in all countries should target: 1. Description of the circulating strain; 2. Early detection and reporting of the potential pandemic strain in animals; 3. Early detection and reporting of the potential pandemic strain in humans [1]. In terms of the countries affected by a pandemic threat, health authorities should also determine the extent of the outbreak and determine if human-to-human transmission is occurring and the efficiency of transmission.

Public health surveillance is central to the process of disease prevention [16]. The modern concept of public health surveillance is the ongoing, systematic collection, analysis, and interpretation of health data to describe and monitor a health event, closely integrated with the timely dissemination of these data to those who need to know [17]. Surveillance data are used both to determine the need for public health action and to assess the effectiveness of programs. Public health surveillance has been recognised as an early warning system, a crude indication of the occurrence of unusual disease patterns [16]. The discrete steps in the processing of health event reports by surveillance systems are depicted in the flow chart in Figure 1.

![Flow Chart](https://via.placeholder.com/150)

**Figure 1** The major steps in a public health surveillance system [17]
Among the many potential sources of surveillance reports, four are commonly used in disease surveillance systems at the state and local levels: physicians, diagnostic laboratories, infection control practitioners (ICPs) and specialty units (e.g. hospitals) [18]. Disease reports are then made to either the state or county health department, depending on the policies established in that state. It is here that the first step in the feedback process begins; cases are followed up to assure that appropriate preventive intervention takes place.

At this level, the person who is designated to perform the follow-up, such as a public health nurse or a disease intervention specialist, must frequently contact the physician who managed the case, or the ICP who has access to the patient’s medical record, to obtain information about the treatment that was given if appropriate for the disease [18]. Analysis of surveillance data takes place at the state health departments, the CDC, and in some large county and city health departments. At all levels, analysis identifies trends, affected populations, and potential target groups for the disease prevention activities [18]. Then, feedback to reporting sources occurs at all levels in the system.

Rapid reporting even when cases are not confirmed can help health department assure needed laboratory specimens are collected, and allow control measures to be undertaken before disease spreads to the point where it is difficult to contain. Surveillance represents constant vigilance to assure effective control or elimination [19]. Delays in reporting are variable and depend on the strength of the surveillance system and the public health ties with the clinical community. Although delays can occur at any point in the process, it is the time between diagnosis and report to the state or local health department that is most lengthy [20]. The replacement of pencil and paper with eHealth applications has provided the public health professional with the capability to perform surveillance more efficiently on common conditions [16]. For example, electronic health records (EHR) systems with clinical decision support functions support internal and external epidemiological investigations of clinical health of aggregate patient data for use in identifying health risks from the environment and/or population in accordance with jurisdictional law [21].

The implementation of eHealth is resource-costly, whereas developing countries have limited financial and technical resources [2], adversely affecting access to eHealth applications. However, the massive penetration of mobile phone networks, especially in developing countries, (i.e. about 4 billion people have mobile phones) potentially enhances access to ubiquitous healthcare services [9]. This is an encouraging sign for the use of mHealth with mobile phone networks in developing countries as a cost-effective alternative to the more traditional Web based eHealth applications to facilitate influenza pandemic surveillance.

3. The potential of mHealth in developing countries

mHealth describes the application of mobile telecommunication and multimedia technologies in mobile and wireless health care delivery systems [22]. In broad, it involves using wireless technologies to transmit and enable various data contents and services which are easily accessible by health workers through mobile devices such as mobile phones, smart phones, PDAs, laptops and tablet PCs [8]. Health services are inadequate in many developing countries because they are often neither accessible nor affordable. When health services are available, they are often dysfunctional, low quality, and unresponsive to the needs of patients [23]. The poor condition of health care in developing countries is widely documented as shown in Table 1. The statistical figures indicate the dire situation of primary health care in developing countries [24].

<table>
<thead>
<tr>
<th>Countries</th>
<th>Infant Mortality rate (per 1000) in 2006</th>
<th>Maternal Mortality (per 100000) in 2005</th>
<th>Years of life lost due to communicable disease (%) in 2002</th>
<th>Births attended by skilled health personnel (%)</th>
<th>Hospital beds (per 10000)</th>
<th>Total Health workers (per 10000)</th>
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For every 5300 people in developing world, there are only 11 hospital beds. Five percent of the population has access to computers whereas 43% of the population own mobile phones [8]. Indeed, Mobile phones, as an ICT platform, have far greater penetration than computers, and are potentially capable to meet the underserved health needs of patients [9].

A recent study of United Nations Foundation and Vodafone Foundation (2009) shows that there are fifty-one mHealth programs that are being operated in 26 developing countries around the world. These programs are gaining strong support across regions as well as from different stakeholders like technology providers, government and academia [8]. Different types of mHealth services are in practice, which include text (SMS) & video contents and voice (medical call centres) services. In Uganda, a local mobile phone company in collaboration with the Aids Information Centre provides bulk SMS messages to clients to provide proper education on AIDS. The aim of the program is to make people aware of AIDS through voluntary counselling and HIV testing. Similar services are also available in Nigeria in the ‘Learning about living’ project, in which people are made aware of AIDS through text messaging. In Georgia, a similar awareness program is run through video contents. In India, information on HIV/AIDS is provided in an engaging and fun way through mobile game services [8]. The games are tailored to target users from different social and demographic groups and run on more than 100 types of mobile phones ranging from basic models to sophisticated smart phones.

4. SMS-based mHealth for influenza pandemic surveillance

FrontlineSMS is a free open-source software package created for Non Government Organizations in the developing world. Using only a PC and a cell phone, FrontlineSMS creates an SMS- based communication hub that can be used anywhere with cellular network coverage without requiring an Internet connection. It is compatible with most pre-2004 model mobile phones that can connect to a PC via a USB cable. The FrontlineSMS program itself runs on the PC and the mobile phone needs only a SIM card and SMS messaging capabilities. The core functionality of the program is scalable, two-way messaging; the user creates a contacts list in the FrontlineSMS program (Figure 2) and SMS messages can be sent to any number of one’s contacts.

![Figure 2 Screenshot 1](image-url)
SMS messages are also received; all incoming messages to the mobile phone are automatically uploaded into the FrontlineSMS computer module and sorted by sender. All messages, outgoing and incoming, are stored indefinitely and can be easily searched. The only associated costs are the normal charges for SMS messages. Advanced functionalities include specifying keywords; when incoming messages contain a certain word or phrase, FrontlineSMS can be configured to perform several actions including pre-programmed SMS reply messages, email forwarding, data extraction for surveys, and more. FrontlineSMS can also be integrated with the Ushahidi mapping software package so that incoming messages can be automatically mapped via a Google maps platform [28] (Figure 3).

Although not written specifically for health care, FrontlineSMS has been used in that area in several different locations, notably at St. Gabriel’s, a rural hospital in western Malawi. The hospital serves an area of 100 miles in radius and a population of 250,000 with only two physicians. The physicians at St. Gabriel’s rely on a network of volunteer Community Health Workers (CHWs) to deliver many of the primary healthcare services to the population within the hospital's service area. However, due to poor communication and transportation infrastructure, communication between the hospital and the CHWs is extremely limited [25]. To obtain any information from the hospital, the CHWs have to walk up to 100 miles or ride on a bicycle or oxcart if available. Communication between CHWs in different areas is nearly nonexistent. In 2008, Josh Nesbit of FrontlineSMS: Medic equipped 100 of the CHWs with mobile phones and installed a laptop to run FrontlineSMS at the hospital. FrontlineSMS increased the ease of communication tremendously. CHWs could now communicate instantaneously with the hospital, and vice versa. According to Nesbit, FrontlineSMS “allows the hospital to respond to requests for emergency medical care, track patients, record HIV and TB drug adherence, stay updated on patient status, mobilize remote communities for outreach testing, provide instant drug dosage/usage information, and connect HIV/AIDS support group members.” The whole project was extremely inexpensive; the mobile phones were recycled, the laptop was donated and the ongoing cost (of SMS messages) is less than US$10 per week [25].
In this hypothetical scenario, we envision a new strain of influenza emerging in a rural area of western Malawi. Reliable information delivered in a timely manner is extremely important during an infectious disease outbreak, but without FrontlineSMS, the healthcare staff at St. Gabriel’s, and regional, national and international health organisations that rely on reporting from St. Gabriel’s, operates with little access to up-to-date information. If a novel influenza strain were to emerge in one of the 700 villages in St. Gabriel’s service area, crucial response days or weeks would likely be lost before a CHW is notified of an unusual infection, the CHW is able to notify the hospital staff, the hospital staff has the opportunity to visit the infected patients, and then inform the regional health authorities. If a pandemic is declared, the hospital staff would have the unenviable job of informing 600+ CHWs and 250,000 citizens of the situation through walking visits, an occasional motorbike trip and the odd phone call. The WHO has identified the necessary and desirable functions of surveillance when responding to a pandemic [1]; accomplishing the basic tasks such as determining the extent of outbreak, mortality and morbidity due to the influenza strain would be difficult enough without a reliable communication network, much less recommended actions like pneumonia surveillance and counting essential workforce absenteeism.

If a FrontlineSMS network between the hospital and CHWs in a developing country had already been in place before the emergence of the new influenza strain, the network could have been utilised as a surveillance tool to assist in the pandemic response. The first cases of the novel flu would likely prompt an SMS from the local CHW to the hospital (Figure 4); when the disease spreads to other villages and does not respond to conventional medications, the hospital would be quickly informed by the CHWs and a physician dispatched to inspect the situation.

The physician could then immediately contact the regional health authorities about the novel influenza strain (Figure 5).

Important developments and messages can be relayed to every CHW within seconds via one mass SMS (Figure 6), a process that could have otherwise taken days or weeks. Performing the WHO recommended surveillance actions would also be much easier with the FrontlineSMS network.

A survey could have been designed to collect the most important information from the CHWs – location, number of infected persons in his or her village, if one profession is infected more than others, number of deaths per day, etc. – and the surveys completed via SMS by the CHWs as often as necessary, for the duration of the pandemic (Figure 7).

FrontlineSMS can automatically extract the data from those incoming messages into a spreadsheet for analysis by the hospital, national and international authorities (Figure 8).

Effective surveillance is reliant on a flow of information that is fast and reliable. As shown above, surveillance with FrontlineSMS is orders of magnitude more efficient than without.

Figure 4 Screenshot 2

Figure 5 Screenshot 3
In the WHO’s pandemic preparedness checklist, the introduction contains a hypothetical scenario showing how easily and quickly a pandemic could spread across the world. It is no coincidence that the authors have envisioned the novel influenza strain emerging in a remote village; one of the crucial factors in the scenario allowing the virus to achieve widespread outbreak is a one month delay from the time of initial infection to the WHO authorities being notified\cite{26}. Surveillance and communication are two key areas of pandemic response in which developing countries lag behind developed countries because of poor communication and transportation infrastructure. Mobile phone technology can be used to overcome many of the obstacles presented in developing countries to effective surveillance in a pandemic. FrontlineSMS relies on the simplest mobile communication tool – 160 characters of text – and limited technology, yet we have shown how much of a difference it can make in a situation where the flow of information is crucial. It is a multi-functional tool; in normal times it functions as a primary care communication tool but can be quickly utilised for other activities, such as surveillance, when needed. Many developing countries rely on CHWs to provide primary health care because of a critical lack of physicians. Often these CHWs do not receive appropriate levels of medical training, support and supervision, which negatively impact the quality of care they provide\cite{27}. One way to address this problem is to establish effective communication links between the CHWs and physicians. As shown in Malawi, FrontlineSMS is an effective way to create a communications link between CHWs and physicians in a way that is applicable to developing countries.

5. Conclusions

This paper has discussed the use of mobile wireless technologies to improve the access to healthcare by the population, especially in rural areas and developing countries where the ICT infrastructure is developing. The study was conducted in the context of healthcare needs in the event of an influenza pandemic outbreak, a potential disaster the world is fearful of. The paper has shown that mHealth promises to improve healthcare services (e.g. accessibility) in the developing world in a variety of ways. In this paper we have highlighted one area, public health surveillance during an influenza pandemic response, in which mobile technologies can be used to achieve more efficient and reliable reporting systems.

This research has used the FrontlineSMS platform that appears to have a number of advantages in the context of developing countries, such as low start up
cost, no need for an internet connection and the ability to run for several hours without a power source. It leverages technology (regular mobile phones) that is already widespread in the population; and the program itself is extremely user friendly and requires little training.

However, the platform needs to be supported by a functioning surveillance application and appropriate organisational policies and procedures. If FrontlineSMS was in place but the CDC of Malawi did not have the resources to test the new strain of virus, or engaged in a cover-up, the SMS network would be of little use.

This study used a purely hypothetical scenario; but translating those possibilities to reality will require rigorous validation. In the future, empirical studies are required to validate the possible benefits of mHealth for public health surveillance. Further, other mHealth features (not supported in Frontline SMS) which have relevance to public health surveillance need to be evaluated.

6. References


