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# Applying information and communications technologies to collect health data from remote settings: A systematic assessment of current technologies

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ABSTRACT

Modern information and communications technologies (ICTs) are now so feature-rich and widely available that they can be used to "capture," or collect and transmit, health data from remote settings. Electronic data capture can reduce the time necessary to notify public health authorities, and provide important baseline information. A number of electronic health data capture systems based on specific ICTs have been developed for remote areas. We expand on that body of work by defining and applying an assessment process to characterize ICTs for remote-area health data capture. The process is based on technical criteria, and assesses the feasibility and effectiveness of specific technologies according to the resources and constraints of a given setting. Our characterization of current ICTs compares different system architectures for remote-area health data capture systems. Ultimately, we believe that our criteria-based assessment process will remain useful for characterizing future ICTs.
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## 1. Introduction

The rapid emergence of the novel H1N1 influenza A in the spring of 2009 served as the latest indication that new and re-emerging infectious diseases pose a serious threat to global public health. This threat is compounded by international air travel, which facilitates disease transmission across distant urban centers more quickly than within countries [1–3]. Since global disease surveillance becomes critical for the early detection of outbreaks [2], it is mandated by international law: the revised International Health Regulations, which entered into force in 2007 and are legally binding on 194 countries, specify core national capacities for detecting and reporting events that may constitute a public health emergency of international concern [4]. Nations can enhance their compliance with the IHR, and so minimize the critical time in an outbreak from detection to disclosure, by establishing electronic surveillance systems based on ICTs for health data collection, transmission, and processing.

Though new infectious diseases are disproportionately likely to emerge from resource-limited countries that lack surveillance [5], most electronic disease surveillance systems are deployed in industrialized countries that have greater access to ICTs. Since infectious diseases do not respect political boundaries, all nations stand to benefit from advanced disease surveillance capabilities. That said, special efforts must be directed towards assisting resource-limited countries to implement surveillance tools that are appropriate for their local needs and resources [2,6]. Capturing health data from remote settings, such as rural areas of resource-limited countries, may prove challenging due to their rugged environment and limited infrastructure. Since the United Nations' 2007 Revision Population Database projects that nearly half of the world's population will still be living in rural areas in 2015 [7], detecting infectious disease outbreaks in those areas will likely compel this challenge to be met.

The collection and transmission of health data from the point-of-entry (PoE) into a central surveillance repository are key functions for the success of any disease surveillance system [2]. Fortunately, technological advances have yielded ICTs which can now be used to capture health data from remote settings. For example, the International Telecommunications Union estimates that cellular phones reached nearly half of the developing world "at the end of 2008 – from close to zero only ten years ago" [8]. Additionally, some technologies have been designed specifically for use in remote settings, such as the XO Laptop and satellite phones [9,10]. Data captured using ICTs can be as, if not more, comprehensive than paper-based health data in two respects. It can be structured, which would allow for the automated submission and analysis of data, as well as the ability to reuse the collected data and combine it with other data sources to more clearly ascertain the situation under surveillance. It can also concisely store patient-level data details.

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Several systems have been developed to capture health data from remote areas for disease surveillance [11–15]. These efforts suggest that no single ICT can satisfy every setting's data capture needs, but rather that different combinations of ICTs may work best in different settings. This article expands upon prior work by defining and applying a general process to characterize ICTs for health data capture across remote settings.

## 2. Background

A review of remote-area health data capture systems [11–15] indicated that they share three main components: communications networks (networks), data capture devices (devices), and data capture applications (applications). Networks are the physical communications infrastructure over which data are electronically transmitted, from the PoE to a central surveillance repository. Devices are usually[1] forms of hardware that physically collect data from the user, and transmit data over the network. Applications are software that provide user interfaces (UI) to the devices: they determine how the user can interact with a device, and specify how the user-entered data are encoded for transmission over the network. Given the three types of components, the system architecture is the integration of a particular set of component implementations into an end-to-end system that captures health data. Definitions of other key terms and table headings in this article can be found in Appendix A.

Generally speaking, the components relate to each other in three ways. In practice, the circumstances of the local environment and system deployment, such as cost limits, narrow the combinations of ICTs that can potentially be used together. First, the networks that are accessible from a remote setting constrain which devices and applications can be employed to capture data. Second, each application captures data with the same mode of latency, level of detail, and support for world languages across different networks. Third, a device that can communicate over a network typically provides support for all applications which are capable of running on that network. Based on the relationship among the components, a criteria-based process was developed to assess the ICTs available for each component, and help select those ICTs which satisfy the constraints of a given setting. The process is explained below.

## 3. Objectives

We created a process to characterize ICTs that remote-area health workers (users) could use to capture health data from remote settings. This process focuses on answering two overarching questions:

1. How *feasibly* could an ICT be integrated into a remote-area data capture system?

   Feasibility pertains to the level of resources that are needed for fielding an ICT in remote settings, including infrastructure, costs, and user training.

2. How *effectively* could an ICT be used to capture health data?

   Effectiveness pertains both to the timeliness and comprehensiveness of the data captured, as well as to the ICT's expected performance in the field.

[1] Software programs can also technically be considered "devices" when they are composed of both applications and the logic to capture data.

Since the acceptable limits of feasibility and effectiveness will vary by remote setting, this work is meant to simply highlight the questions, tradeoffs, and design decisions that must be considered when architecting a remote-area health data capture system.

## 4. Methods

### 4.1. Overview

Each step of the process compares the available implementations for a single system component against a common set of cost and feature criteria. These technical criteria were established based on our domain expertise in computer science and public health, and are defined in Appendix A. To demonstrate how the process can be applied, commodity (commercially- or freely-available) ICTs that existed during the study (April–July 2009) were identified and characterized. Technical specifications were obtained primarily by browsing manufacturer and reseller websites for advertised costs and features.

### 4.2. Process for selecting feasible and effective data capture architectures

1. Identify the communications network(s) that are accessible in the proposed setting. Characterize accessible networks based on their performance and capabilities.
2. Assess applications supported by the accessible networks against criteria for data reporting and world language support.
3. Determine which devices are capable of communicating over the accessible networks.
4. Compare devices on the basis of operational criteria, such as cost, performance, and additional resource needs. Select those devices that are appropriate for the remote setting.
5. Consider different architectures for remote data capture, given the remaining networks, applications, and devices. The best approach will depend on the data capture environment, funding constraints, and time frame for deployment.

## 5. Results

### 5.1. Step 1: identify and characterize accessible communications networks

Eight categories of networks were identified. These networks are listed by decreasing order of penetration in Table 1, which summarizes each network's level of penetration, features, and different generations (if applicable). Of the eight networks, only the cellular telephone and data network is deployed in varying generations across the world [16,17]. The satellite communications networks were characterized by one service provider each, because those providers offer the widest level of global coverage. The satellite telephone network was based on the Iridium network [10], and the satellite broadband network was based on Inmarsat's Broadband Global Area Network [18].

Table 2 outlines each network's costs, including requisite hardware, and performance in terms of data speed. Two categories of terrestrial networks offer wireless high-speed Internet connectivity. The mobile broadband network was based on the IEEE 802.16e standard which is being adopted worldwide [19]. The 3G cellular telephone and data network works with a wider range of applications, but its data speed is roughly half that of the mobile broadband network. One other wireless high-speed network (long-range Wi-Fi) is not included because of its nascent stage of maturity [20–22].

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