Chapter 37

Public Health Emergencies: Informatics in Tracking the Ebola Virus Disease Outbreak in Liberia

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Take-home messages:

- Accessible and user-friendly mobile applications can be effectively deploy communities for effective epidemiological surveillance in an Ebola virus disease epidemic.
- The acceptance and utilization of mobile application in community during Ebola epidemic and other Public Health response hinges on trust and respect.
- An effective surveillance and sustainable system for diseases of epidemic proportion basic should integrate mobile application with innovations for that provides reliable power source and signal strength.

The Background

This chapter explores the use of technology for active surveillance of disease outbreaks and public health emergencies. To illustrate this, the chapter will focus on the real life application of mobile phone technology for active surveillance of the Ebola Virus Disease (EVD) during both intense and low-level transmissions of EVD in several communities surrounding Monrovia, the capital city of Liberia.

The most deadly, complex and largest outbreak of Ebola Virus Disease originated in early December 2013, from a tiny village in Guinea and eventually engulfed Sierra Leone and Liberia. These three countries are in West Africa [10, 11]. However, the EVD outbreak in Guinea was not officially reported until March 2014 [1, 2, 3, 5, 9]. As of February 2015, the EVD outbreak in West Africa accounted for 22,525 cases (confirmed, suspected and probable), with Liberia accounting for 42% (8,745) of these cases. Liberia also accounted for 42% (3,746 out of 9,004) of all of deaths resulting from the EVD. By September 2014, which was the peak of the outbreak in Liberia, the country accounted for 49% of all of the cases (approximately 6,500 of the total 13,200 suspected, probable, and confirmed) [1, 2, 5]. Greater than 50% EVD cases in Liberia occurred in Montserrado County, which accounts for a third (1.5 million) population and has the seat of the capital city, Monrovia [6]. Most of the Ebola deaths that occurred in Montserrado County were in the densely populated urban and peri-urban communities in Monrovia [2, 5] (Figure 37.1). These sprawling slums like West Point, New Kru Town tend to accelerate the spread of the EVD [4]. This is further complicated by the continuous movements of contacts, which leads to secondary transmissions and infections in the densely populated county.

Figure 37.1: Rural and Urban Montserrado, showing the 22 Epidemiological Zones

Densely populated urban centers pose challenges to an effective Ebola response including loss to follow-up, explosive Ebola deaths from in- and out-migration of contacts, and the fluid nature of the movements in the city.

Overview of the Community-based Initiative (CBI) Model

The critical epidemiology-surveillance response in Montserrado County combined community-based active surveillance and the application of mobile technology to actively track transmission in all communities. The Community-Based Initiative (CBI) was developed by the author and others to break the transmission chain in Montserrado County and its densely populated capital Monrovia. The initiative (Figure 37.2) involves working with local community leaders and youth groups to conduct house-to-house searches for those with potential signs of EVD in order to rapidly isolate potential cases from the population. It involves simple door-to-door surveys by community leaders, women, youth, and other key stakeholders.

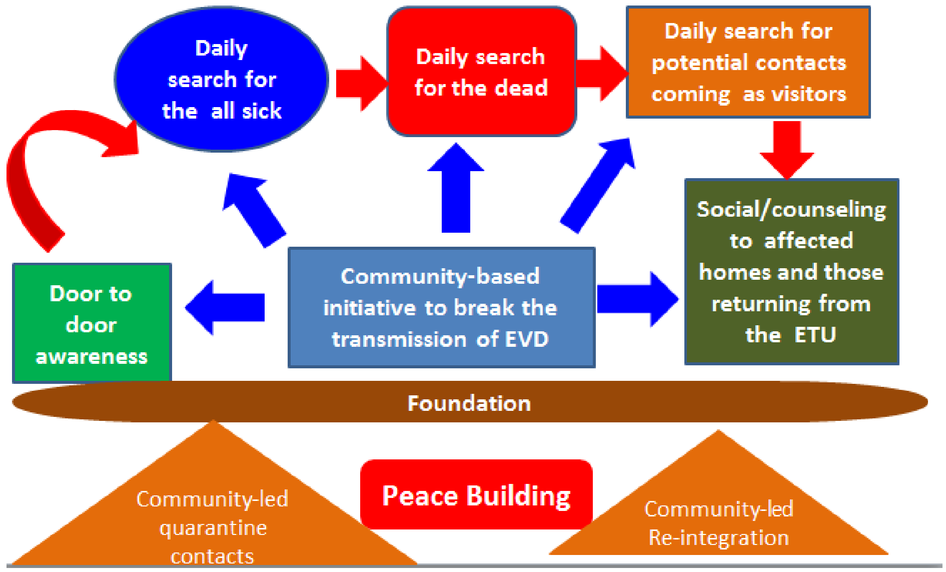


Figure 37.2: The five strategic pillars of the Community-based Initiative (CBI) Model

The CBI model was initially developed and successfully implemented in the urban slum of West Point. It was developed as a result of the military quarantine, following reports that there were secret burials of potential Ebola victims and that the sick were being hidden from the authorities due to distrust of the government's response to the disease. These two factors were deemed responsible for the explosive outbreaks of the infection. Working with the local leadership in West Point, including the Commissioner, we were able to discover 34 deaths that had not been reported. We were then able to identify and trace all of their contacts. There was enhanced discovery of sick people in the community and prompt referral to the Holding Center for immediate transfer to the Ebola Treatment Unit (ETU). As a result, many cycles of EVD transmissions in the very highly congested West Point slum were averted. The active case finders and the local leaders developed a mechanism for community-based quarantine of contacts to further prevent the spread of the Ebola infection. As a result of the success in West Point, the model was sucessfully scaled-up in several Ebola hot-spots in and around Monrovia to actively seek out Ebola cases and thus break the transmission of EVD at the community level.

The goal of the CBI model was to get the local authorities to accept the realities of Ebola and mount an active surveillance in their communities in order to stop the transmission cycle (Figure 37.3). The stages of the model included the following events:

(1) Engage communities in mass meetings to review the Ebola situation and propose bottom-up strategies to eliminate Ebola from the respective communities.
(2) Plan community mapping of all houses, blocks, communities, zones, and districts for reporting.

(3) Conduct training in simple messages and active case finding.
(4) Provide logistics and set-up a reporting structure (mobile application).
(5) Dispatch a locally selected active case finding team in community where 1 active case finders works around 25 houses (1:25 houses) and initiate the process.

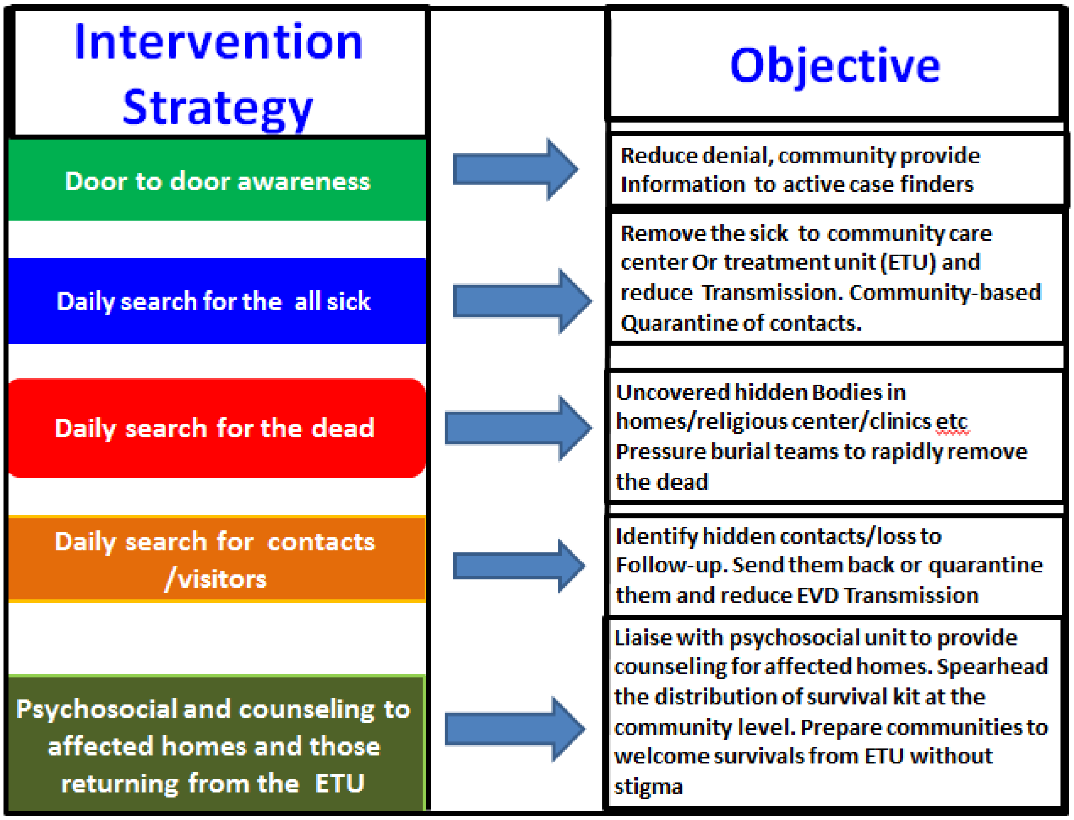


Figure 37.3: The Objectives of the CBI Model in the fight against the EVD

Introduction of Mobile Application in the CBI Ebola Surveillance

When the CBI model was first launched in West Point, data was collected daily and sent via SMS messages. The key data that was collected everyday by the active case finders and their supervisors included: the total number of houses visited, the total number of sick people, the total number of dead bodies, the total number of patients sent to the Ebola Treatment Unit (ETU), and the total number of visitors to the household. After collating data downloaded from the SMS messages, the information was sent as an email to the Chief Medical Officer (CMO) at the Ministry of Health and Social Welfare (MoH&SW). This method of data collection, transmission, and utilization posed serious difficulties to scale-up to about 66,000 houses from the original 5,300 houses in West Point. A paper-based data collection form (Figure 37.4) developed by the team was introduced. These forms would come a few days late, although a summary of the data continues to come near real-time via the SMS messaging.

Because the use of paper-based form to collect and report data in combination with the SMS messaging was leading to delays or loss of crucial epidemiological data from the ACF in the community, a system to integrate community-based tracking using cell phone technology linked to a central database at the project's head office was needed. Thus, daily updates would be captured in real time to collect data, including coordinates of infected homes using GPS technology.

Ministry of Health & Social Welfare
Community Based Initiative - Forms for Active Case Finders

DATE:__________ COUNTY: __________ DISTRICT: __________ WARD/ZONE: __________ COMMUNITY: __________

Date	Block	1 # House-holds	2 # Sick	3 # Sick in ETU	4 # Dead	5 # Burial Teams Responding	6 # Visitors	7 # in Quarantine	8 # Completed Quarantine	9 # Orphans	10 # Needing Counseling	11 # Needing Food	12 # Surviving EVD

NAME OF ATIVE CASE FINDER __________ Date Submitted__________ Signatur__________ Phone __________

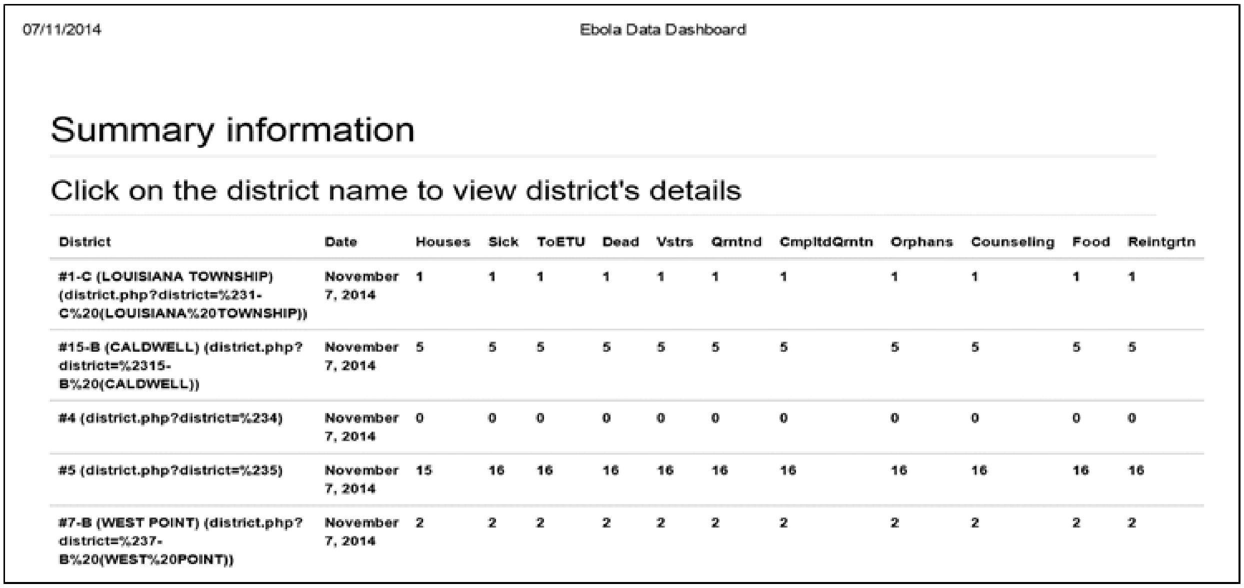
NAME OF COMMUNITY LEADER __________ Date Verified__________ Signature__________ Phone __________

Figure 37.4: Paper-based Form Developed to collect EVD Surveillance from the Community by ACF

The data required included: suspected cases, visitor movements (a main source of major outbreaks), surveillance of religious centers, make-shift clinics, and herbalist centers in the communities. These centers have repeatedly served as reservoirs for continuous EVD transmission. There were great need for data that captures dangerous practices such as the washing of dead bodies and secret burials.

In order to rapidly implement a response that would effectively break the transmission of EVD within the dense and mobile populations of Monrovia and Montserrado County, a mobile application was developed through a partnership with academia that would track community level data on transmission drivers. The mobile application was crucial for the successes of the CBI model. The paper-based form was converted into a cellphone application. The application was hosted and co-managed at

Yale University; the issue of security, privacy, and access was jointly addressed by the teams from Liberia and the United States.


07/11/2014 Ebola Data Dashboard

Summary information

Click on the district name to view district's details

District	Date	Houses	Sick	ToETU	Dead	Vstrs	Qrntnd	CmpltdQrntn	Orphans	Counseling	Food	Reintgrtn
#1-C (LOUISIANA TOWNSHIP) (district.php?district=%231-C%20(LOUISIANA%20TOWNSHIP))	November 7, 2014	1	1	1	1	1	1	1	1	1	1	1
#15-B (CALDWELL) (district.php?district=%2315-B%20(CALDWELL))	November 7, 2014	5	5	5	5	5	5	5	5	5	5	5
#4 (district.php?district=%234)	November 7, 2014	0	0	0	0	0	0	0	0	0	0	0
#5 (district.php?district=%235)	November 7, 2014	15	16	16	16	16	16	16	16	16	16	16
#7-B (WEST POINT) (district.php?district=%237-B%20(WEST%20POINT))	November 7, 2014	2	2	2	2	2	2	2	2	2	2	2

Figure 37.5: Mobile Application developed by the Yale Team and loaded by our IT to cellphones

The mobile application project was piloted in the Caldwell Township, one of the Ebola hotspots. The team from Yale acquired 25 mobile phones, loaded the application and used them for the initial pilot phase of the project. Because of the limited number of phones, a combination of cell phone and paper-based reporting was employed. This required driving over bad and impassable roads in Montserrado to collect the paper reports. At times, summaries of these reports had to be sent via an SMS text or called in by the ACF supervisors. As a result of these challenges, only monthly summary reports were available. There was delay in the reporting to the Ministry of Health and Social Welfare and the National Ebola Incident Management System (IMS). Furthermore, separate reports were created and sent to the World Health Organization (WHO) and to the United Nations Development Program (UNDP), since they were responsible for different geographical regions. Copiling the separate reports and other paper-related delays led to monthly reporting instead of daily reporting became major barriers to mounting an immediate Ebola response. These delays made it difficult to submit the required epidemiological reports that were need to advise the key decisions made by the National Ebola Incident Management System (IMS). After more cell phones were deployed, daily reporting became possible (Figure 37.7).

District	Houses	Sick	Sick ToETU	Dead	Safe Burial	Visitors	Quarantined	Completed Quarantined	Orphans	Needing Counseling	Needing Food	#Survivors Reintegrated
#1-C (Caresburg)	965	45	0	1	0	0	0	0	0	0	0	0
#2	44,626	12	0	0	0	87	1	0	0	1	1	1
#3	23,892	39	0	11	3	233	20	1	0	0	0	1
#6	61,137	101	1	2	0	732	0	0	27	0	0	0
#8	9,435	65	12	5	3	120	0	12	0	0	0	0
#9	2,125	21	2	2	1	130	0	0	0	0	0	0
Total	**142,180**	**283**	**15**	**21**	**7**	**1302**	**21**	**13**	**27**	**1**	**1**	**2**

District	#Houses	#Sick	#Sick ToET	#Dead	#Buried	Visitors	#Quarantined	Need Food	Need Counseling	#Completed Quarantined	#Orphans	#Reintegarted
#15	2666	157	5	7	4	224	19	128	272	6	177	0
#16	1980	49	17	74	40	168	59	121	60	105	58	17
#4	2321	46	12	66	35	163	58	109	48	105	52	11
#11-Dixville Township	418	8	0	0	0	2	0	0	0	0	0	0
#15-B (Caodwell)	2613	10	0	1	0	42	90	4	16	94	16	3
#15-C (New Georgia Town Center)	432	10	0	0	0	27	58	43	3	101	58	0
Total	**10,430**	**280**	**34**	**148**	**79**	**626**	**284**	**405**	**399**	**411**	**361**	**31**

Figure 37.6: (A) WHO districts cases summary report for November 1 to December 5, 2014. (B) UNDP districts cases summary report for the Month of November, 2014.

Partner	Zone	#Houses	#Sick	#SickToETUs	#Dead	#Safe Burials	#Visitors	#Quarantined	#Completing Quarantine	#Orphans	#Require Counseling	#Require Food	#Reintegrated
UNDP	1600	3,949	0	0	1	0	3	0	0	0	0	0	0
UNDP	100	290	0	0	0	0	1	0	0	0	0	0	0
WHO	1100B 2	3,445	3	0	0	0	7	0	0	0	0	0	0
UNDP	1100 B1	245	0	0	0	0	0	0	0	0	0	0	0
WHO	1100 A2	4,939	8	0	0	0	11	0	0	0	0	0	0
WHO	500	379	0	0	0	0	0	0	0	0	0	0	0
UNDP	400	398	11	0	0	0	2	0	0	0	0	0	0
WHO	1400	1,910	0	0	0	0	9	0	0	0	0	0	0
WHO	600	130	0	0	0	0	0	0	0	0	0	0	0
TOTAL		15,685	22	0	1	0	33	0	0	0	0	0	0

Figure 37.7: Montserrado County Cases Summary Report For January 21,

Challenges and Future Directions

In spite of the success of the CBI model to effectively use a mobile application to track EVD cases in communities, there were numerous challenges during the course of the epidemic in Liberia. A discussion of the challenges faced will help future teams rapidly develop deployable mobile application during epidemics. The IT team in Liberia lacked access to the backstage of the data, and as a result, it became difficult and almost impossible to correct field level mistakes and errors. As a result, the local IT staff had to send an email to Yale to correct these errors before they could be reflected in our reports. This created glitch in the real-time reporting and tracking mechanism. The developer of the mobile application did not provide a means for the local IT team to make correction to the date of data entry. Hence, there was no capability to correct for data that were not sent on a current date. There were other constraints posed by the mobile application for the end user: the tendency of the mobile application to freeze (leading to difficulty in uploading and obtaining real-time data), the lack of a tool for graphical analysis within the mobile application, and the need to export the data into Excel or copy and paste before analysis was done.

The absence of some basic local infrastructure to support effective utilization of the mobile application was another bottleneck. For instance, the lack of a constant power source in remote areas to charge the phones caused a delay in receiving constant information. Finding a constant power source from the cell phone companies is an important priority. The absence of a strong cell signal in some of the most remote parts of the county was another constant source of frustration for the end user in data transmissions.

There were challenges between the end user and our IT team in ensuring that the local capacity was developed to consistently collect and transmit the data via the mobile phone application. Firstly, the IT teams did not provide the needed large-scale training in the use of the applications, considering the low-level computer literacy in the nation. Secondly, there were some instances where some supervisors were late in submitting data. This led to parallel reporting of data by some local community leaders as they bypassed their delinquent supervisors. Finally, there were instances of inadequate and random supervision by monitors and IT associates to ensure data quality.

The CBI model clearly demonstrated that a robust mobile application can greatly enhance an epidemiology-surveillance system for EVD and other infectious disease epidemic in very challenging communities. The success of such a model hinges on the development of an enduring relationship of trust with the communities and their key stakeholders [7, 8]. A combination of community trust and an easily accessible mobile application is critical to the epidemiology-surveillance activities of EVD [12, 13]. Hence, this model can be amplified for use in future outbreaks in complex urban populations. This can be achieved through partnerships with institutions that will invest in developing more robust mobile applications. This will help us transition to post-Ebola early warning systems in the community, while maintaining functionality for any future Ebola outbreaks. This mobile application must be capable of functioning in normal health services to track other diseases concerning public health (malaria, diarrhea, Acute Respiratory Infections, maternal and child mortality), as well as help with the continuous active surveillance that will quickly identify and respond to future Ebola outbreaks. However, there are crucial components that must be taken into consideration to make mobile applications user friendly for local managers and IT teams. Such a user-friendly application must have the following characteristics:

(a) The ability to provide backstage access to local IT associates.

(b) A cheap power source for charging phones and identifying alternative signals for remote places.

(c) A training component that will build the capacity of the local user and mangers to implement a robust monitoring and supervision system as well as higher data quality.

Results

As shown in Figure 37.6, the combination of the mobile application and the CBI model produced dramatic results. For the period of November 1 to December 5, 2014, data was collected from 152,610 houses. The results are as follows: (a) 563 sick persons were identified, (b) 59 of these sick persons were taken to the Ebola Treatment Unit (ETU) as suspected and/or probable cases, (c) 169 dead bodies were found in the community, (d) 86 of these dead bodies were safely buried by the authorized burial teams, (e) 1926 visitors were tracked in the various communities, and (f) 305 homes were quarantined to reduce interaction with other members of the communities. Other crucial pieces of data that were collected included Ebola-related orphans, homes needing counseling, and those who have been integrated into the communities after completing their quarantine.

Conclusions

The foregoing results clearly demonstrated that a combination of mobile applications and a unique Community Based Intervention contributed to the dramatic reduction in Ebola cases in Montserrado County. As shown in the figure below, developing a system to collect and transmit real-time data for analysis and decision-making is critical in the fight against the EVD and other infectious diseases in developing countries [12, 13, 14]. Such a system can be used in the future for reducing the transmission of EVD in densely populated urban populations.

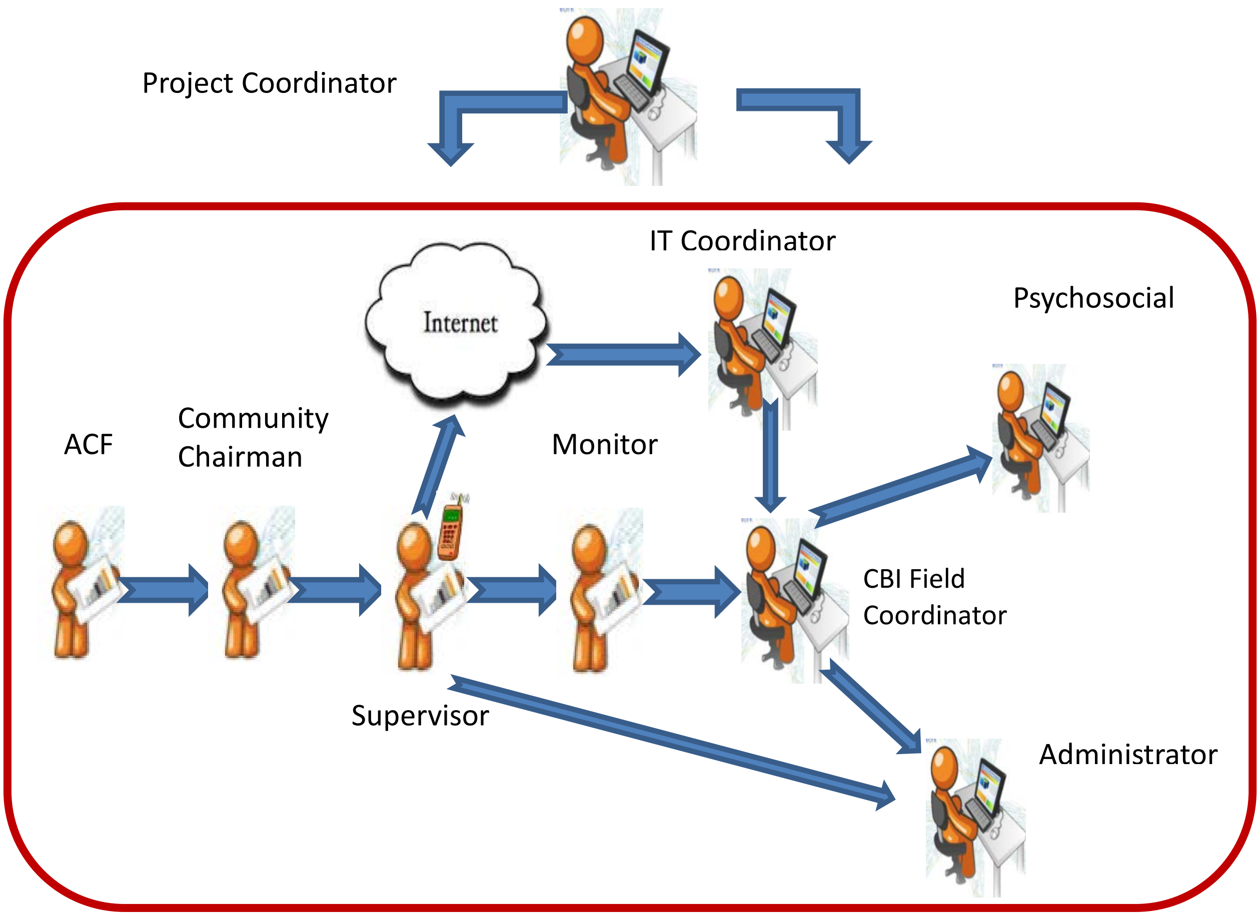


Figure 37.8: Model Data Flow Diagram used in the CBI Model to fight EVD in Monrovia and Montserrado County

The timely reporting, analysis, and feedback of crucial data during Ebola response and any Public Health emergencies is crucial in mounting a robust response [12, 13, 14, 15, 16].

Discussion questions

1. What are the critical roles of mobile applications in reducing community-level transmissions during an Ebola virus epidemic?

2. What elements should be taken into consideration when developing a user-friendly mobile application during a major epidemic such as Ebola?

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