FluPhone Project: Tracking Human Contacts for Understanding Epidemic Spread in Real World

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Overview

This study records how often different people (who may not know each other) come close to one another, as part of their everyday lives. To this end, we ask volunteers to install a small piece of software (called FluPhone) on their mobile phones and to carry their phones with them during their normal day-to-day activities. The software will look for other nearby phones periodically using Bluetooth, record this information, and send it back to the research team via the cellular phone data service. This information will give us a better understanding of how often people congregate into small groups or crowds, such as when commuting or through work or leisure activities. Also, by knowing which phones come close to one another, we will be able to work out how far apart people actually are, and how fast diseases could spread within communities. We are also asking participants to inform us of any influenza-like symptoms they may experience during the study period, so that we can match the spread of flu to the underlying social network of encounters made.

Apart from the above study, the FluPhone software has an extended function called 'Virtual Disease', where we conducted real-time simulated epidemics of 'virtual' diseases, which only get transmitted between participants' phones as a message when they encounter each other.

1. How did you get the idea to create FluPhone? What was your inspiration?

In 2007, we were working on a computer communication protocol in mobile environment without Internet. Thus, communication should happen among devices in a decentralised fashion. We were investigating a new protocol for efficient data dissemination. The mobility pattern of the mobile devices is not random and is heavily influenced by the social patterns and daily life of the users. This brought us to measure the people's movement/connectivity using Bluetooth equipped sensors and mobile phones to understand the dynamics of the human contact networks, which can be presented as a time series of graphs.

An article called 'The Wireless Epidemic' in Nature, 2007 by Jon Kleinberg says 'As wireless communication technologies spread, so the potential for viruses to exploit them grows. Biological models of virus transmission will assume new relevance for assessing the emerging threat'.
This article inspired us to give an idea of the efficient data dissemination in the mobile networks could be an epidemic spread, and we intensively worked on integrating such biology inspired idea.

Around the same time, the epidemiologists, who worked on modelling SARS and other infectious diseases approached us. They were desperate to obtain human contact information from the real world. In general, the epidemiologists work on small-scale network data, which could be synthetically built up, or extracted from the diary based contact information. We came up a project idea 'FluPhone'. The goal of the FluPhone project was not only building up the epidemic model, but also understanding the change of the human behaviour in the epidemic situation. Individuals may change their behaviour for several reasons: through being ill themselves, having to care for others who are ill, or through changing their normal habits in the belief it will prevent or minimise their risk of infection. Overall, understanding the epidemic spread in reality and the outcome can be used to form any strategy for the movement control. FluPhone project was run back in 2009 - 2011 at the time of post SARS.

2. How did you get FluPhone to be available for people? Why was its success limited? Do you think if you launched FluPhone now it would be more accepted and used?

The FluPhone study was originally experimented in Cambridge, UK, where we advertised it study via the channels listed below. Targeting participants include university members, their families, colleagues, friends, and people who work or live in Cambridge. Cambridge is a typical University town and majority of the population connect to the University. The population of Cambridge is about 120,000.

- Secretary of department - distribution for the members in the department
- Secretary of publicity in college - distribution for the members on the college
- Bulletin boards (e.g. Students bulletin, Graduate Union)
- Cambridge University based societies
- Facebook and Twitter (e.g. Cambridge graduate students, Alumni)

We have received good responses during the initial experimental study within the computer laboratory for improvement of the software and information on the web page. However, during the public experiment stage, we were not able to obtain many volunteers. The reasons for this could be as follows:

- The study period was off the academic term
- The flu was not on main news at that time
- Top-up SIM contracts are not free (although we offer free 5GBP top-up)
- Not 100% coverage of mobile phones that can run FluPhone. Note that the J2ME capable phones by major manufactures are supported and at the later stage of the project, we have implemented FluPhone over Android phones, too.

In the past 10 years, smart phone culture, market, and business models have changed completely along the social media's dramatic evolution. Deploying FluPhone as a Smart phone function now is a completely different story. Also, the current devastating situation of COVID-19 epidemic calls for better information, from epidemic modellers and governments to general public. I believe FluPhone would be well accepted in the current COVID-19 situation. Note that the privacy/security issues have changed a lot past 10 years, which have to be well addressed if new FluPhone software will deployed.

3. How was FluPhone intended to work? What kinds of location-based technology and tracking tools were used to help track users symptoms?

The FluPhone study aimed to understand how fast flu and other infections can spread within the UK. To do this, we used participants' mobile phones as part of a scientific experiment to see how many people the participant and other participants encounter during his/her normal activities. We have written some special software to run on mobile phones which lets us work out how often participants encounter other people, using the Bluetooth feature which is common in most mobile phones.

There are two features of the software, which will be of use to the user as well as collecting important information which will help scientists and medical researchers understand better how infections, like influenza, spread within the UK.

1. The software will automatically detect and record how many Bluetooth devices are around you, how often you encounter these devices, and will send this information back to the study team. This provides us with an approximation of how many people you would meet at any one time.

2. The software will let you tell us if you feel ill with any flu-like symptoms. This will hopefully enable us to see how social encounters and travel can directly spread infections.

There are two things that this study aims to do:

1. Let you tell us if you feel ill with flu like symptoms. This will provide researchers with a clearer picture of where swine flu is in your community;

2. Provide researchers with important information about the day-to-day pattern of encounters of people in your area, from which we will gain a better understanding of how fast infections, like flu, may spread.

FluPhone does not record the physical location information and does not use GPS information. In 2011, common mobile phones do not have GPS. It records the device information within the proximity range using Bluetooth communication protocol. Bluetooth is a low-power open standard for Personal Area Net-works (PANs) and has gained its popularity due to its emphasis on short-range, low-power and easy integration into devices. The software will look for other nearby phones periodically using Bluetooth communication, record this information and send it back to the research team via the cellular phone data service (e.g. GPRS or 3G). The proximity detection by Blutooth was ~5m (but the range is adjustable now), which did not give very accurate proximity information for flu. At a later stage we moved on to the RFID tag based solution, where we combined Raspberry Pi network to collect RFID data. In the case of COVID-19, ~5m might provide good information…or other techniques (e.g. WiFi etc.) can be combined in current smart phones. Once somebody is diagnosed as 'COVID-19 positive', registered members who had been in the proximity range can be identified which can be traced in succeeding hops. This could be helpful to identify the root of the spread. Those information can be visualised in a heat map to identify the hot spot. We have also implemented 'virtual disease' in Smartphones: if you are close to the pathogen holder's phone, it alerts based on the programmed epidemic model. Note that GPS does not work indoor. The battery life increased a lot past 10 years, and I do not think that will be a problem of Bluetooth communication running in background.

The technology has proved robust with reliable data collection at initial level. However, for tackling reliable network modelling for epidemiology requires further 'massive' and precise experimental data from general population. The FluPhone project aimed at such massive scale data collection, which is the first attempt of using mobile phone as far as we are aware back in 2011. This is a difficult challenge to obtain a certain amount of data from people's phones without handing a special device to each of them, which makes Bluetooth appealing for experiments involving a large quantity of people since Bluetooth communication is equipped almost all mobile phones.

4. How did you protect the users' privacy?

The privacy issue was a tough challenge. We have written almost 50 pages of ethical documentation for the FluPhone project. All data provided by participants or collected by their mobile phones was only used for the purposes of this research, was stored securely and was not made available to anyone outside of the research team, in accordance with the Data Protection Act.

At the time of user registration, the users were required to provide their consent. By agreeing to download and install this software, the participants were indicating that they are willing to take part in this study, they have read and understood the software disclaimer, and that they are willing to allow their data and the information that the software collects on their phones to be used in scientific research. Also participants must be over 12 years old (under 16s require parental/carer consent), have the use of a compatible mobile phone, and permission from the owner and bill-payer of the phone to participate.

To participate in this study, the user must:

- read, understand and agree with the consent and study information;
- have access to a compatible mobile phone;
- read, understand and agree with the FluPhone software disclaimer;
- agree to download and run the FluPhone software application on their mobile phone;
- agree for the FluPhone application to use the Bluetooth function of their mobile phone;
- agree for the FluPhone application to send the data it collects to the study team via their network connection , and that this may incur a cost to the bill payer of the phone;
- be willing to allow their data and the information that the FluPhone software collects on their phone to be used for scientific research by the study team.

A clear description of data processing procedure was provided before their registration process:

Will the software have access to any of my personal information on my phone?
The software will not access any of the participant's personal information on the phone, such as any text messages or call logs, and our program does not send us any information the phones hold.

What will you do with my information?
FluPhone will use the collected information to understand better of how people travel and interact with each other. Currently, not enough is known about people's travel habits to make confident predictions of how infections like flu will spread. Also, by using any flu reporting received, we can perform computer simulations of how flu is spread and try to work out why it appears to spread so quickly in the UK compared to other European countries. Only scientists involved directly in this study will have access to your data, and we will keep all data secure. We will relay our summaries and findings to the Department of Health, to help them plan during future outbreaks and pandemics.

What will you do with my data?
We take the security of your data very seriously. All information we receive will be analysed anonymously, and only members of the study team will have access to the data; the database will not be shared with any third parties. We do not ask for your full name or address (unless you are lucky enough to win the prized draw), and all analyses will be performed on an anonymised dataset in which e-mail addresses and mobile phone identifiers (such as Bluetooth MAC addresses) have been removed. The data will only be used for the purpose of research into how influenza and other close-contact infections can spread within the UK. The data will be kept securely in the Cambridge Computer Laboratory, where it cannot be accessed without permission.
A data monitoring committee will be appointed, consisting of experienced medical researchers who are not directly involved in the survey to give advice about data confidentiality issues.

Who will have access to the information I provide?
The information you provide about yourself at registration on the website and the information we collect from your phone (Bluetooth information and if you report any flu-like symptoms) will be sent directly to the researchers, and will not be linked to your name (we don't collect your name at any point in this study), so we have no easy way to identify you by the information we receive. All of your information is protected under the Data Protection Act 1998, in a similar way to your normal phone calls and text messages and mobile phone location. We will safeguard your data in accordance with the data protection act, and will not disclose your data to any other party. Your data will be stored securely at Cambridge University and only researchers involved in this study will use your data for the research aims described above. We will keep the data secure for 3 years after the end of the study grant (until 1 August 2013) and then all the data we collected will be destroyed.

What if I don't want to participate anymore?
You are free to stop participating at any time, even when you've installed our software on your phone. If you wish to stop participating in the study you can simply stop running the application on your phone, or uninstall our software from your phone. If you wish for any data you may have provided via our website (information about you) when you registered, or that has been collected by our software on your phone to be destroyed and not used in our study then you need to tell us in writing to the study leader at the address below or via email flu-phone@cl.cam.ac.uk, stating the details you registered with us (including your username and mobile phone number).

5. Why are tracking apps necessary? How can they help prevent further COVID-19 outbreaks or other viral infections?

The current devastating situation of COVID-19 epidemic needs more information for epidemiologists and governments to general public. We lack reliable evidence on how many people have been infected or who continue to become infected.

COVID-19 has led people in a number of countries to develop tools similar tp FluPhone. For example, in South Korean an app allows people to see the date a COVID-19 patient was confirmed to have the disease and the places the patient visited. Currently available tracking mobile apps have already provided better information for understanding the epidemic spread to the participants. However, it can be far more powerful on understanding how the virus can be spread from person to person and the cluster of people (community) to another community in time-dependent manner. A time-dependent graph of connectivity among phones can be constructed, detailing the duration and frequency of interactions between participants. Dynamic contact graphs can potentially provide important insights of the epidemic spread to help the epidemiologists, governments, and the public. Examples are:

1) Duration-weighted pairs: time spent in close-proximity is a powerful determinant of infection risk, and these can be considered as a weighted link between individuals with location and context associations.

2) Number of encounters per person: are some individuals responsible for a disproportionate number of contacts?

3) Social distances: betweenness and centrality measures describe how far apart individuals are in a network which strongly impacts disease dynamics.

4) Community structure: identify individuals that form bridging links between otherwise distinct groups offers efficient targeted interventions.

Analyses of epidemic models by computer simulation have been useful for understanding the dynamics of disease spreading. Accurate and reliable models of human social interactions are key to decide on effective strategies to prevent further spread. What are the patterns of epidemic diffusion, and how do interactions among people affect the epidemic spread? Daily human interactions in the real world are complex, and the quantitative understanding such dynamics is vital. Capturing human interactions provides an empirical, quantitative measurement of social interaction patterns to inform mathematical models of the spread of close-contact diseases. Good visualisation will help the public's understanding of COVID-19 and its spread and it will help the effective deployment of the government policy.

Without enough immunity established within the community, the COVID-19 epidemic would come back even after the quarantine period is over. Contact networks extracted from mobile tracking apps can take a vital role to help preventing a second wave of the epidemic.

6. How would you reassure users that using a tracking app won't expose them to data breaches?

See the question 4 on the privacy issues.

There will be many mobile tracking applications, which deploy different privacy/security solutions, which will introduce complication when the mobile apps are deployed over many countries. Currently an effort on building a unified protocol is going on based in EPFL Switzerland called **Decentralized Privacy-Preserving Proximity Tracing** (DP-3T https://github.com/DP-3T) project, where the project aims at providing standards, technology, and services to countries and developers realising privacy-preserving approach. DP-3T does this by using a proximity-based technique - frequently switching up the broadcast messages over time, so that you can't track the same person in multiple known locations over long periods of time. All mobile tracking applications should follow such collaborative way to develop and deploy mobile tracking applications to tackle COVID-19. As DP-3T says the virus has spread quickly and knows no political boundaries. The Google / Apple contact tracing project has very similar protocol as the DP-3T protocol. To bring it under control, we must act in the same manner; speed and international cooperation are essential to protect health, privacy, and the economy.