Contact Tracing Over a LAN Network

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Abstract (All)

Contact tracing is a method of monitoring potentially harmful connections between individuals. This can use Bluetooth, GPS, and Wi-Fi among other wireless communication protocols that keep records of user connections. These connections can be leveraged to match users within the same network and across multiple networks. These logs, combined with algorithms for matching users and scoring risk, can be used to quantify and mitigate risk to users.

Traditional manual contact tracing methods are time-consuming and limited in their efficiency. To overcome these limitations, networking technologies have been used to develop automated contact tracing systems. The reliability of these systems can be compromised by false alarms and contact detection inaccuracies. Therefore, if data is collected accurately, the exploration of network technologies in contact tracing is essential because these technologies can leverage the power of data and connectivity to effectively control diseases and benefit public health.

In our research we simulate a workplace or school environment that may use several wireless access points to provide LAN coverage. Our work leverages the use of these access points in order to approximate the position of users and predict whether or not they have been in contact. This allows network administrators to monitor the transmission of illnesses and notify contaminated users in advance. Implementing this system will bring about a new era of contact tracing that is fast, accurate, and convenient for users and administrators.

Why Needed (Andrew)

Contact tracing is a public health strategy used to identify persons who have come into close contact with infected victims. Contact tracing is almost always related to contagious diseases and is used as a control mechanism to reduce the spread of said diseases. Some examples of infectious diseases where contact tracing was needed are Ebola virus, COVID-19, smallpox, tuberculosis, and some Sexually Transmitted Diseases like HIV just to name a few. Contact tracing is needed to identify potential new cases before they infect others. In other words, the process is used to detect minor cases before they expand.

Furthermore, contact tracing is not only used to identify individuals but also diagnose individuals who have come into close contact with infected persons. Contact tracing processes usually curtail their findings and sort preliminary diagnoses into categories. Examples of diagnostic categories include positive, negative, and false positive and false negative. The separation of results into categories for thorough analysis processes helps prevent adverse implications of deceptive results;[11] Misleading results can expose a non-infected person to the disease in a cohorted area. Misleading results can also assign more resources to an uninfected person who was false positive when those resources can be utilized elsewhere.

One other reason for the need for contact tracing is that [1] “Tracing is associated with improved outcomes across pathogens with diverse transmission dynamics and across a variety of settings. “Analysis of past studies constructed from contact tracing helps track the dynamic evolution of diseases over time. This improves efficiency and productivity of scientific research. Fortunately, this can be a relatively fast process especially when implemented digitally. It makes use of electronic information to track infection exposures. Consequently, this addresses scalability, notification delays, recall errors and contact identification in public spaces. Contact tracing technology improves our overall understanding of disease dynamics and substantially minimizes the spread of diseases.

Main Objective (Chris)

The main objective of this research is to examine the accuracy of contact tracing systems and provide a comprehensive understanding of these systems. In this paper, we will employ simulation techniques of disease spread to further our understanding of these systems and explore how accurate a contact tracing system can be. Moreover, we will explore traditional contact tracing systems and identify potential weaknesses and limitations. We will do this by evaluating other simulations and understanding how traditional contact systems work. Some questions we will attempt to answer are identifying scenarios where these methods are challenged in terms of speed, privacy, scalability, and precision.

By employing a simulated environment that mimics real world scenarios, we seek to investigate the effectiveness and limitations of existing contact tracing systems. After simulating these scenarios with varying degrees of complexity, we will evaluate the ability of contact tracing systems to pinpoint and accurately identify individuals at risk. After our research is completed, we hope to gain insight into the precision, speed, and reliability of these systems, ultimately contributing to the enhancement of public health strategies and the development of more robust contact tracing protocols. Our concluding remarks will emphasize the importance of contact tracing and highlight avenues to overcome identified limitations.

Achieving Objective (Alex)

This section will discuss specific methods and technologies deployed to implement contact tracing. It will extensively cover smartphone Bluetooth low-power technology as a peer-to-peer method of opt-in contact tracing. It will directly cite “Evaluating How Smartphone Contact Tracing Technology Can Reduce the Spread of Infectious Diseases: The Case of COVID-19" from IEEE Access to further explain the technology and its viability for disease tracking. It will also cover privacy concerns related to that topic. For this, it will directly cite “The need for privacy with public digital contact tracing during the COVID-19 pandemic” from The Lancet. It will additionally cover access-point based contact tracing. Finally, it will compare the two deployment models mentioned.

Evaluation (All)

Data Generation and Environment Development (Andrew)

The environment portion of code is to generate a 2-D matrix which represents people in space. Ones represent positives and twos represent negatives. If a user at any index happens to have at least one positive around them (represented by an adjacent cell, they have the potential of being positive and will be stored in an updated version of the matrix that represents if they contracted the disease based on their previous location in the matrix.

User Input (Chris)

The User input portion of the code is to accept points that the user chooses from the visual aid described below. A user can select a point by clicking on a specific item in the visual aid. The item will be highlighted and its values will be saved to a list. A point will have an x and y coordinate. These points represent the choice of access points for collecting data on the spread of a disease. A user can add as many points as desired and observe the simulation results after these points are inputted. After the input points are selected, the list of access points is sent to the "Data generation and Environment development" portion of the code to determine the effectiveness of the contact tracing system.

Contact Tracing Computation (Hayden)

The contact tracing portion of the code is the culmination of the data generation, user input, and visualization. First, a prompt asks users to input their environment information including the arrangement of wireless access points. Next, the data generator is called to generate a realistic scenario that we can use to capture results. This environment is filled with users at random and each user is given a location in our 2D map at each point in time.

Using the transmission power of the user's devices, the transmission medium (usually air), the frequency, and the distance between the user and the access point we can determine the power that would be received by the access point. If the sensitivity of the wireless access point is below the power received, then the user is considered to be within range of that access point. The user's position is then approximated from the received power (assuming we do not know the true location of the user) using as many access points as possible.

This process is performed at every point in time for each user up to time t. When two users are found to be close in proximity at the same time step their IDs are collected and a confidence is computed. This confidence value comes from how sure our system is that those users were in positions that would be considered close contact. This data is then compiled and output as a contact list which can be used to track down contacts between users.

Visualization (Alex)

The visualization portion of the code will aim to provide a two-dimensional visual aid that will represent all of the items of interest to the simulation in a colored grid. Each item will be assigned an integer in the code which will correspond to a unique color on the grid, aiding in the user's understanding of both the visual representation and the simulation itself. The code will include a timing system so that the progress of the simulation can be viewed while the rest of the program runs.

Conclusion (Hayden)

This research demonstrates the feasibility of using wireless access points to triangulate the positions of users and approximate with a level of confidence as to whether or not they were in close contact. This confidence dramatically increases when users are within range of more than one access point. If the users are within range of 3 access points we are able to successfully triangulate their positions and determine contact with high confidence. Results level out after a user is within range of more than 3 access points. Using our simulation, users are able to simulate their own arrangements and view their expected results if they were to implement this system.

This system allows contact tracers to conveniently monitor and predict user's health as long as they are connected to the network. This system bypasses any app requirements and does not add any additional effort from the users. This technology is significant because users are less likely to download and maintain an app than they are to connect to a local area network. Beyond contact tracing this technology can be used for many things, for example clocking users into and out of work as soon as they walk through the door.

This technology may give rise to some ethical concerns. People might not like the idea of being tracked when they are simply trying to connect to a LAN network at their school or office. However, we do encourage network administrators to include a page that is displayed prior to connection that lists the terms and conditions of the network and it's tracking policies. Additionally, we discourage any tracking purposes that are not for the benefit of the users. We feel that moving into the future of medicine will be incredibly beneficial to be able to diagnose an illness before it even has time to manifest.

Our next steps for this project are to further build out and refine our code base. This includes improving our data generation strategy to produce more authentic results, refining our user input method for map overlay and adding more input functionality, developing our 3-dimensional visualization such that it shows the progress of the simulation over time, and increasing the number of access points that we can currently accommodate in our simulation. Additionally, we see a potential to utilize collision checking methodology by adapting this environment to be seen as a 3D space with axes for x, y, and time. Then a search algorithm, such as breadth-first search would be also to search the space for all possible collisions. This does get tricky however with the uncertainty that comes with an insufficient number of wireless access points. We also had some ideas for improving our confidence in situations where there might only be one or two access points in range: using previously known locations and eliminating areas that we would expect a connection within. These ideas will give us plenty of room to build on this challenging, but engaging, project.

References (All)

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Appendix

All

Our GitHub project directory: https://github.com/Feddockh/Contact_Tracing_Using_Networks.

Chris Erfort

The articles read were [8], [9], and [10]. Article [8] provided a simulation that helped us understand the functionality of traditional contact tracing systems. Article [9] provided a potential innovation in AI that can make contact tracing better. Article [10] provided a code library that can simulate Bluetooth devices, which could be used in future simulations for contact tracing systems. I wrote the main objective section and the user input subsection within our simulation section. I am conducting the user input part of our simulation for access point collection.

Hayden Feddock

I read articles [5] and [6] and [7]. These articles all work to perform contact tracing using a network connection. I used these articles as inspiration for my work on this project, using signal strengths from users to determine user proximities. My work includes the development of the project idea and laying out the framework for the simulation. In doing this, I developed templates for the User, Environment, and AccessPoint classes. I also developed the compute_loss and compute_distance functions as well as the main. I also made a template for the data_generator in order to test the functionality of my main function. In order to develop as a team we are using GitHub. You may view my contributions on the Hayden branch here. For this paper I modified the abstract to include a description of our simulation (which we were lacking last time), wrote the contact tracing subsection of the Evaluation section, and wrote the conclusion for this paper.

Alex Ivensky

I read articles [2], [3], and [4]. These articles cover a range of topics related to contact tracing, including smartphone Bluetooth-based contact tracing, privacy issues related to contact tracing, and a more general overview of contact tracing in the context of public health. My work includes citing these articles to discuss how contact tracing is implemented and privacy concerns that can be associated with various implementations. I am also developing a visualization program for the simulation which will provide a time-based visual aid for our simulation. It will also provide figures that will be used within the paper itself to provide further visual aid for the reader.

Andrew Andoh

I read articles [1] & [11]. Both articles work hand in hand to detail procedures in contact tracing. They talk about data analysis strategies, severity of results obtained in first stage of analysis and what to do with them, considers role of contact tracing to improve efficiency of research that have to do with infectious disease dynamics, and finally point out the need for contact tracing. Reference [12] helped me generate my code that randomized the positions of users and assigned them their respective statuses in relation to their surroundings; This is the basis of contact tracing.

```
%{write users class
%each has x,y position
%create no of users and randomize pstn
%input for number of positives
classdef Environment
    properties (Access = private)
        Size_X = input('Dimensions of x-coordinate?\n');
        Size_Y = input('Dimensions for y-coordinate\n');
        Steps = input('How many steps do you want\n');
        %matrix to represent users and their position
        disp("The following matrix represents users in a space and their positions\n")
        xx = input('Enter integer for number of rows you want \n')
        yy = input('Enter integer for number of columns you want \n')
        Num_Users = xx * yy;
       % Users
         A = zeros(xx,yy); %empty the matrix first
         B = zeros(xx,yy); %updated matrix with positives and negatives

          % matrix
        for i=1:xx

            for j=1:yy
                A(i,j) = randi(2); %assign specific position a random val from 1-2
            end
        end
            disp(A)
            %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
            % for corner indices
            if A(1,2)==1| A(2,1) ==1
                B(1,1)=1;
            else
                B(1,1) =0;
            end

             if A(xx,2)==1| A(xx-1,1) ==1
                B(xx,1)=1;
            else
                B(xx,1) =0;
             end


              if A(1,yy-1)==1| A(2,yy) ==1
                B(1,yy)=1;
            else
                B(1,yy) =0;
```

```
            end


             if A(1,yy-1)==1| A(2,yy) ==1
               B(1,yy)=1;
           else
               B(1,yy) =0;
             end


              if A(xx-1,yy)==1| A(xx,yy-1) ==1
               B(xx,yy)=1;
           else
               B(xx,yy) =0;
           end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

           %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
           %%all indices excluding corners

         for k=2:xx-1
             for l=2:yy-1
                 if A(k,(l-1))==1 | A(k,(l+1))==1 | A(k+1,l)==1 | A(k-1,l)==1
                     B(k,l) =1; %%assigning positive(1) to index with at least one positive around them
                 else
                     B(k,l) =0; %% assigning zero
                 end
             end
         end
           %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    end
    methods
        function obj = Environment(x, y, steps, num_users)
            if nargin > 0
                obj.X = x;
                obj.Y = y;
                obj.Steps = steps;
                obj.Num_Users = num_users;
            end
        end

        function users = getUsers(obj, step)
            users = obj.Users;
        end
    end
end
```