Covid-19 Contact Tracing through Multipath Profile Similarity

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ABSTRACT

Contact tracing is a key approach to control the spread of Covid-19 and any other pandemia. Recent attempts have followed either traditional ways of tracing (e.g. patient interviews) or unreliable app-based localization solutions. The latter has raised both privacy concerns and low precision in the contact inference. In this work, we present the idea of contact tracing through the multipath profile similarity. At first, we collect Channel State Information (CSI) traces from mobile devices, and then we estimate the multipath profile. We then show that positions that are close obtain similar multipath profiles, and only this information is shared outside the local network. This result can be applied for deploying a privacy-preserving contact tracing system for healthcare authorities.

CCS CONCEPTS

• **Networks** → **Location based services**; • **Applied computing** → *Health care information systems.*

KEYWORDS

CSI, WiFi, Indoor Localization, Contact Tracing

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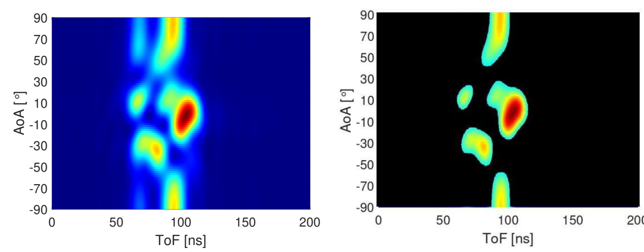
1 INTRODUCTION

The pandemic has raised the need for technological solutions in order to trace contact events between people. The traditional methods of tracing contacts, such as patient interviews, are time-consuming and insufficient. Based on the above, the majority of European countries have been seeking for app-based contact tracing solutions. Mobile apps that perform proximity measurements using Bluetooth have been created, but for a variety of reasons (e.g. privacy concerns, limited development, unreliable measurements, need to install an app) they are not widely adopted [2] or even not supported at all [1].



(a) 2-D Music spectrum. **(b) 2-D Music spectrum masked.**

Figure 1: 2-D Music Spectrums of one position, representing its multipath profile.

In this paper, we present an initial idea about a WiFi-based contact-tracing application, based on estimating the similarity between the multipath profiles. Rather than using unreliable Received Signal Strength measurements for proximity, which are affected by many factors (such as radio wave reflection from walls or floors) as shown in prior work [4], we propose to estimate the targets' multipath profile. Our intuition is that, if two mobile devices are close, then the multipath profiles of these two positions should be similar. In other terms, environmental reflections observed by two different users would be similar. We next discuss why this idea can be a promising first step for contact tracing. Finally, we analyze its functionality and highlight the difficulties that will be addressed in future work.

2 PROPOSAL

We take advantage of the Channel State Information (CSI) matrix, which can be extracted from commodity Access Points (APs). CSI matrix contains one complex number $CSI_{i,j}$ per subcarrier and per received antenna at the AP. CSI fully characterizes the signal propagation between the transceivers, thereby being of interest for studying the multipath profile. CSI is calibrated as proposed in [5].

With regards to the localization algorithm that is used to obtain the multipath profile, we rely on SpotFi [3]. At first, SpotFi applies the Smoothing Algorithm to increase the resolution, adapting the dimension of CSI matrix by grouping antennas and subcarriers.

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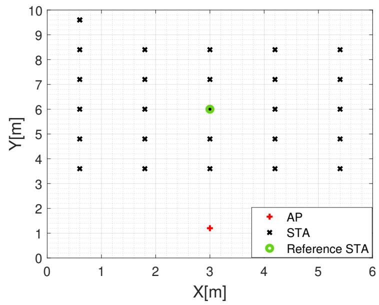
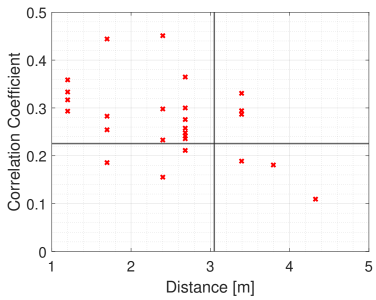
[1] https://www.elespanol.com/omicrono/software/20221010/cierra-radar-covid-aplicacion-gobierno-coronavirus-funcionar/709679160_0.html



(a) Testbed.



(b) Correlation Coefficients and distances from reference position.

Figure 2: Testbed map and Spectrum Similarity Results.

Then, it applies the 2-D MUSIC algorithm to estimate the multipath profile for every target device, through the 2-D MUSIC Spectrum. An example of resulting image is shown in Fig. 1a, where the x-axis indicates the Time of Flight (ToF) and the y-axis the Angle of Arrival (AoA). Red colors in the image indicate strong peaks in the spectrum. The rest of SpotFi algorithm, that includes how the target is localized, is out of scope for this work.

Our idea is to compute the image of the 2-D MUSIC spectrum for each pair of users, and then compute the pairwise similarity metric between these two users in the AP. The reason behind this choice is the fact that spectrum similarity comparison is a privacy-preserving solution, that does not reveal sensitive information like the users' location. The AP would then compute the spectrum similarity. *It will then only send to the public health care authorities the decision of being or not in contact based on the spectrum similarity.*

As for the image similarity part, there is a variety of available methods in the literature [7]. In this work, we use the Pearson correlation coefficient, as proposed in [8]. Moreover, we mention that we estimate the similarity metric after masking the image (Fig. 1b), thereby eliminating the bias caused by the background noise.

3 EXPERIMENTS AND RESULTS

We make experiments using as transmitter a commodity WiFi AP centered at frequency of 5.45 GHz , with a bandwidth of 80 MHz, in an indoor testbed. It is deployed in an office environment, covering a surface of almost 65 m^2 and we use 27 fixed target locations (marked as cross) to test the performance of our system. A map of this testbed can be seen in Fig. 2a. Any WiFi device can be used as a target (STA). Moreover, we estimate the median of the 2-D Music Spectrum over 50 transmitted WiFi data packets, in order to obtain more stable results over sufficiently short time period. Ideally, we would like to obtain high spectrum similarity between the positions that are close (are in contact) and a much smaller correlation between positions that are far away (not in contact).

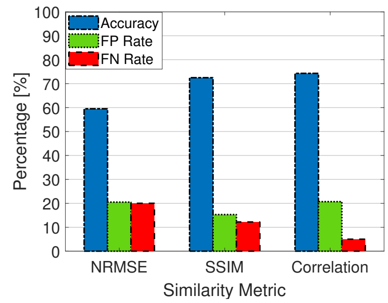


Figure 3: Final Results and comparison of different metrics.

As for the experiment, it has been studied in health science that a Covid-19 patient can infect other people, with very high probability if they are in a distance less than 3.05 m [1] (vertical line in Fig. 2b). Without loss of generality, we set the green circled position in Fig 2a as a reference position. In Fig. 2b we estimate the correlation coefficient between the 2-D MUSIC Spectrum of the reference position and all the others and plot it as a function of their Euclidean distance. Furthermore, we set a dynamic threshold for the correlation coefficient equals to its maximum value divided by 2 (horizontal line in Fig. 2b). If a pair of images has a correlation value larger or equal to this threshold the images are declared as correlated. As we can see, we have an accuracy of $\frac{17}{20} \approx 85\%$ for the high risk positions and a total accuracy of $\frac{20}{26} \approx 77\%$.

In Fig. 3 we can see the final results of our approach for all the different positions that can be used as reference. More in detail, we obtain an accuracy of 74%, whereas False Positive (FP) and False Negative (FN) rates are equal to 20% and 5% respectively. The aforementioned results show that the proposed method is stable regardless of the choice of reference position. Finally, we compare Pearson Correlation Coefficient to Normalized Root Mean Squared Error (NRMSE) and Structural Similarity (SSIM) [7], thus showing that our choice is more accurate compared to them.

In summary, our results are encouraging. Although spectrum images are influenced by the hardware noise, we managed to obtain reliable contact-tracing predictions. As a future work we plan to take advantage of a wide range of information that a localization system can offer, like the time that two people are in contact. Moreover, both network privacy mechanisms, as proposed in [6], and different hardware set ups will be discussed.

4 ACKNOWLEDGMENTS

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