Covid-19 Contact Tracing through Multipath Profile Similarity

Stavros Eleftherakis
stavros.eleftherakis@imdea.org
Imdea Networks Institute
Universidad Carlos III de Madrid
Madrid, Spain

Giuseppe Santaromita
giuseppe.santaromita@imdea.org
Imdea Networks Institute
Madrid, Spain

Maurizio Rea
maurizio.rea@i2cat.net
i2cat
Barcelona, Spain

Timothy Otim
timothy.otim@imdea.org
Imdea Networks Institute
Madrid, Spain

Domenico Giustiniano
domenico.giustiniano@imdea.org
Imdea Networks Institute
Madrid, Spain

ABSTRACT
Contact tracing is a key approach to control the spread of Covid-19 and any other pandemic. 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

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.

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 $\text{CSI}_{i,j}$ 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.

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 m² 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

3 EXPERIMENTS AND 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.

4 ACKNOWLEDGMENTS

The research conducted by IMDEA Networks was sponsored in part by the European Union’s Horizon 2020 research and innovation programme under Grant No. 871249 (LOCUS), and in part by the Regional Government of Madrid and the European Union through the European Regional Development Fund (ERDF) as part of the response from the European Union to the COVID-19 pandemic in the context of REACT-CONTACT-CM23479 research project, awarded under the Agreement formalized between the Regional Government of Madrid and IMDEA Networks.
REFERENCES


