DP-3T Exposure Score Calculation - Summary

27 May 2020

DP-3T Team

Motivation

We are building a proximity-based digital contact tracing system to notify users when they have potentially been exposed to COVID-19 positive cases. A key question in such systems is when to show this notification. In Switzerland, for example, an exposure notification should be shown to a person if that person has been exposed to COVID-positive individual(s) for 15 minutes or more during one day (see Ordinance of 5/13/20 of the Swiss Federal Council). Following the contact duration and distance thresholds established by the ECDC, we focus on close-range exposures, i.e., when a person is within approximately 2 meters of an individual who later reports a positive diagnosis.

Our goal is to estimate exposure representing established epidemiological parameters to the extent possible given the imprecision of the underlying technology.

Background

We measure the exchange of low-power radio packets between smartphones as a proxy for the spatial proximity of smartphone users. Specifically, we rely on Bluetooth Low Energy (BLE) radios. BLE wireless networking capabilities are nowadays available on most smartphones. Since BLE operates in the 2.4 GHz ISM band, it is suitable for short-range device-to-device communication. To detect extended close-range proximity of users, regarded as "exposure", we measure the attenuation of BLE packets transmitted from a COVID-19 positive person's smartphone to the devices carried by people in their vicinity. This attenuation is calculated as the difference between the transmission power at the COVID-19 positive user's smartphone and the power registered at the receiving device (RSSI). It serves as a proxy for the physical distance between the two smartphones and therefore between two individuals[1].

Users periodically check for exposure given information reported by COVID-positive users.[2]. This exposure check is performed several times a day and includes data collected during the current day and over the immediately preceding 9 days. Taking into account information from the preceding 9 days should capture the vast majority of contacts with positive cases. This recommendation is based on current knowledge of the contagious period of SARS-CoV-2, and the incubation period, i.e. the time window from infection to symptom onset (if any), following the ECDC guidelines.

[1] Alan Bensky, "Wireless Positioning Technologies and Applications", Chapter 6, Artech House, 2008.
[2] Carmela Troncoso et al. (2020) *Decentralized Privacy Preserving Proximity Tracing*. Retrieved from https://arxiv.org/abs/2005.12273 on 27 May 2020.

Approach

Our approach for exposure estimation uses measurements of radio signal attenuations of BLE advertisements exchanged between devices over time to build an estimate of exposure.

Figure 1 shows a heat map of attenuation values for individual BLE advertisements of the GAEN protocol measured between smartphones at various distances. This figure illustrates that it is difficult to measure distance based on attenuation in real-world environments, as the signals are rather noisy, well documented in the open literature. The deviations from the simple free-space radio signal propagation model are due to multipath and shadowing effects, resulting from walls, objects, and people, that affect signal propagation. However, in BLE, these errors almost always increase and very seldomly decrease the attenuation. If the attenuation is low (in Figure 1, <50dB), we are therefore highly certain that the two devices are indeed within 2 meters. Higher attenuation values offer less certainty as to distance, for example, attenuation values in the 50-70 dB range (in this experiment) could result from devices that are up to 15 meters apart. Since both transmission power and RSSI measurements can differ across phone models, calibration is applied both at the sending device and at the receiving device to correct for discrepancies.

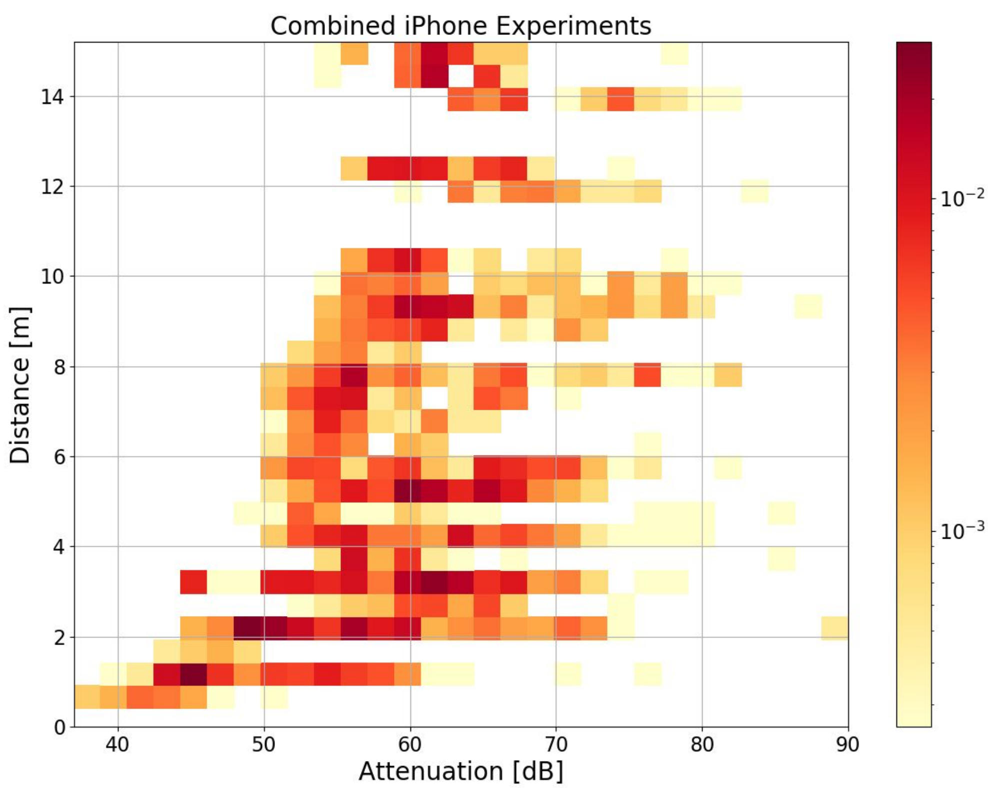

Figure 1.

We do not try to use the attenuation values to accurately measure distances between devices - prior attempts have demonstrated this to be challenging, especially given the diversity of environments and low BLE beaconing frequency. Instead, we focus on solving an epidemiologically relevant problem of detecting (2m) proximity between devices. ***We therefore conducted experiments to estimate the probability of 2m proximity given the measured attenuation value p(d<2m | attenuation), which we then take as the probability of exposure to the COVID-19 positive person at the time of the reception of the BLE advertisement beacon.***

Figure 2 shows the p(d<2m | attenuation) for Figure 1.

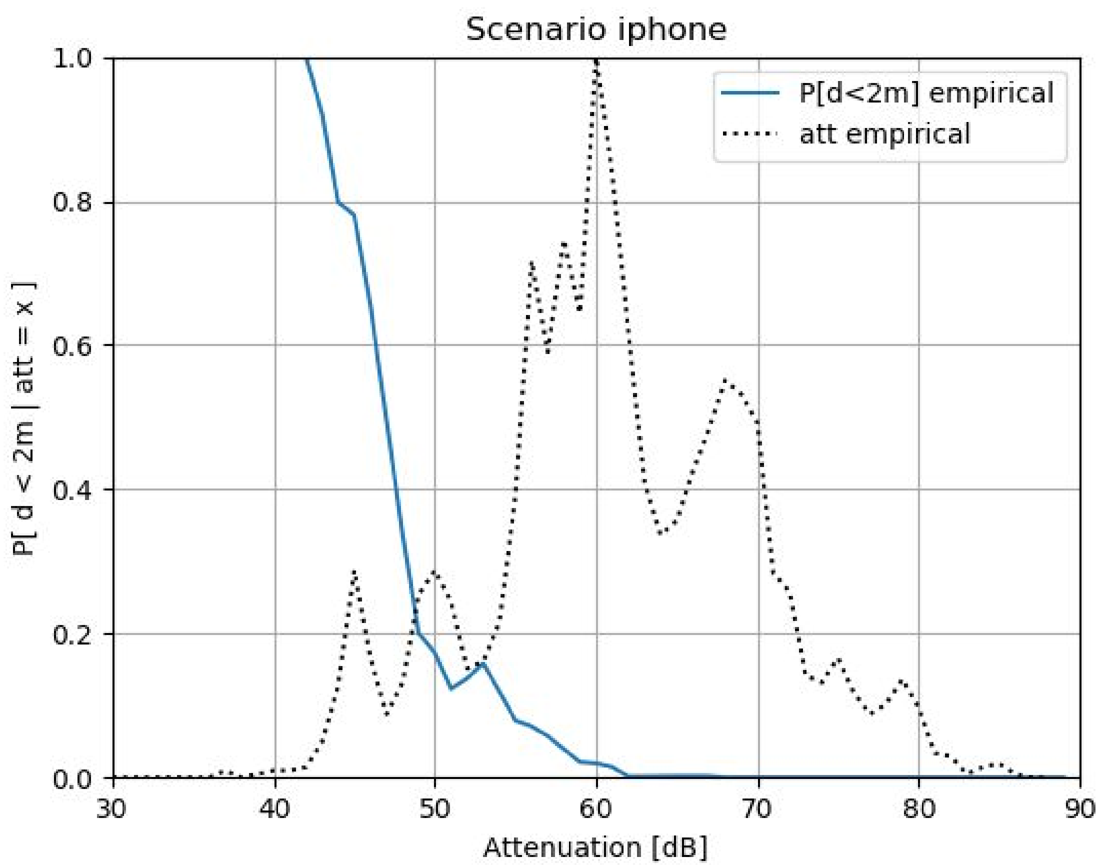

Figure 2.

The current [Google/Apple EN (GAEN)]() implementation exchanges advertisements with neighboring devices every 2.5 - 5 minutes (Figure 3). This means that every received beacon can be seen as an indication of proximity within a few minute-wide interval, while the attenuation level measured for a beacon gives the probability of being within a certain distance from the device emitting the beacon. ***A receiver can, therefore, estimate the overall duration of time it was exposed at an attenuation level (and therefore was likely within distance d) using a set of beacons (and corresponding attenuations) received from one device.***

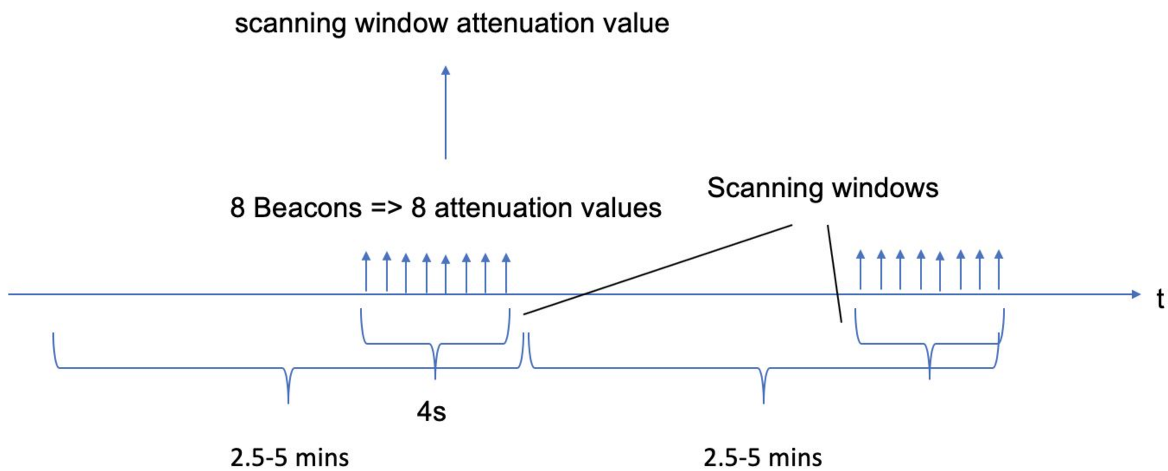

Figure 3.

SwissCovid Exposure Estimation on GAEN

GAEN does not expose individual attenuation values to the tracing application. The API instead allows the app to request duration of “exposure” to COVID-19 positive persons with a coarse granularity (using the `ExposureSummary` API). The GAEN API takes as input two thresholds, `t1` and `t2`, that partition the range of attenuation values into three buckets (`bucket1: (0...t1); bucket2: (t1...t2); bucket3: (t2...)`), and a set of keys corresponding to COVID-19-positive users. The API returns, for each of the three attenuation buckets, the joint duration of exposure to all COVID-19-positive people whose keys were provided as input. The reported `duration_at_attenuation` for each bucket is limited to 30mins.

In the SwissCovid app, we use the `ExposureSummary` API to obtain the **duration of exposure** of the user to COVID-19 positive people within one day, for each of the three attenuation buckets.

We define the **Exposure Score as an estimate of the duration of exposure within 2m proximity.** We calculate it as a weighted sum of the duration within each of the attenuation buckets:

```
ES = w1*B1 + w2*B2 + w3*B3
```

Where `B1, B2,` and `B3` are the durations of exposure in attenuation `bucket1, bucket2,` and `bucket3` and `w1, w2,` and `w3` are the weights associated with each bucket.

Based on our preliminary measurements on the GAEN API, we set the following conservative thresholds and weights: `t1=50dB, t2=55dB, w1=1, w2=0.5, w3=0`. We set `w3` to 0 to discard the exposures in the third bucket as they correspond to large attenuation values and hence most probably large distances between devices.

These thresholds and the weights were conservatively chosen to balance both the precision and recall of exposure notification across a wide range of environments, including home, public transports, office, and public spaces. As Figure 1 and 2 illustrate, attenuation values below 55dB are measured with high probability at distances equal or smaller than 2m.

ES is computed each day for the current and past 10 days. The **exposure notification to the user is triggered if ES is greater or equal to 15min** within any of these days.

The GAEN API is still evolving, and calibration of the measurement of the attenuation values and duration of exposure between iOS and Android, and between different phone models is still not complete. This calibration is being performed by Google and Apple engineers. In the pilot phase, we therefore set our weights, attenuation thresholds, and trigger duration conservatively to minimize false positives. These thresholds will be refined as we collect more data and as more phones receive calibration values.