SwissCovid Exposure Score Calculation

Version of 11 September 2020

Goal

SwissCovid is a proximity-based digital contact tracing system that notifies users when they have potentially been exposed to COVID-19 positive individuals. The key function of digital contact tracing systems is determining when a person is exposed and should be notified. In this document, we describe how SwissCovid estimates exposure using established epidemiological parameters and the technology currently available on smartphones.

Background Information

Epidemiological

The goal of proximity-based digital contact tracing is to support traditional contact tracing. In traditional contact tracing, an index case (i.e., a person with a confirmed Sars-Cov-2 infection) is interviewed in order to identify potential contacts that the index case might have infected. Contact tracers use contact definitions provided by the local health authorities. For example, in most countries, contact tracers use a cutoff of 2 meters and 15 minutes to qualify a contact as sufficiently high risk to justify quarantine.

Digital proximity tracing aims to support this process by notifying these contacts through an app, which has the benefit that non-social contacts can also be notified, even those that an index case would not recall.

It is important to understand that the distance used by traditional contact tracing is an approximation. The distance is a “best estimate” value that offers a practical guideline on which to base a decision but is not an absolute classifier. First, it is, of course, not the case that a contact at 1.9m would be at risk, while one at 2.1m would not be. Second, people are not able to recall contact distances with high precision, and thus the identified contacts will not all have been exactly within a given radius. Bluetooth estimates must be evaluated in this context.

Moreover, traditional contact tracing for Sars-CoV-2 often results in low attack rates (percentage of people identified through contact tracing who end up having been infected), typically around 15% or less. Thus, it is expected (and normal) in contact tracing that a majority of people in quarantine will not have been infected. Epidemiology lacks the predictive power to say which of the identified contacts have been infected and which have not. It is thus prudent that they all go into quarantine (i.e., precautionary isolation).

Bluetooth

SwissCovid measures the exchange of low-power radio packets between smartphones as a method of estimating the spatial proximity of smartphone users. It relies on the Bluetooth Low Energy (BLE) beaconing that is available on most smartphones. Since BLE operates in the 2.4 GHz ISM band, it is suitable for short-range device-to-device communication. BLE beaconing specification does not directly include distance measurement. Instead, distance can be estimated by measuring signal strength, given that radio signals naturally attenuate over distance.

Approach

Exposure estimation predicts the degree of exposure by measuring the reception and attenuation of BLE beacons that are broadcast periodically between devices.

Epidemiologists have defined a contact to be close physical proximity with a COVID-19 positive person or people for a sufficient length of time. In Switzerland, “close” is currently defined as approximately 1.5 meters and “sufficient” is approximately 15 minutes.

To detect the physical proximity of people, we measure the attenuation (diminution in strength) of the radio packets that were transmitted from a COVID-19 positive person’s smartphone to the devices carried by other people in the vicinity. Attenuation is calculated as the difference between the transmission power of the COVID-19 positive user’s smartphone and the power of the signal registered at a receiving device (RSSI). It can serve as a proxy for the physical distance between the two smartphones and therefore between the two individuals[1].

Since both transmission power and RSSI measurements differ among phone models, calibration is required for both the sending and receiving devices to correct for discrepancies and produce a uniform estimate of attenuation between any pair of phones.

The duration of exposure can be inferred from the period of time that the beacons from COVID-19 positive people’s phones were received by another user’s phone. In traditional contact tracing, where one can rely only on human memory of encounters, 15 minutes is the length of an encounter with one person. In the app, which records all encounters, we aggregate the cumulative exposure to one or more COVID-19 positive people into the total exposure to determine if the duration is sufficient.

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[1] Alan Bensky, “Wireless Positioning Technologies and Applications”, Chapter 6, Artech House, 2008.

Relation between attenuation and distance

Figure 1 shows a heat map of attenuation values for individual BLE beacons measured between smartphones at various distances in several socially relevant scenarios (party, office, queue, transport, or eating lunch as a group). This figure illustrates that in real-world environments it is difficult to precisely determine distance from attenuation. For this experiment we evaluated the 5 different scenarios above, collecting a total of 139,837 BLE measurements aligned with ground truth distance. The scenarios followed a strict protocol and the 20 subjects carried different phones which they occasionally used. We inferred ground truth data by recording the scene and processing the data based on a fixed grid, tracking subjects as they acted through the scripts. GAEN calibration was applied to the measured attenuation values.

The signals are rather noisy, which is well documented in the open literature: multipath and shadowing effects affect signal propagation and cause deviations from the simple, free-space radio signal propagation model. Objects, vegetation, and people attenuate signals. The latter do so in particular due to the large percentage of water which is hard to pass through for signals in the 2.4GHz range.

It is important, however, to note that these effects almost always increase, and very seldomly decrease, attenuation. If attenuation is low (in Figure 1, <50dB), we can therefore say with certainty that the two devices were within a few meters of each other. Higher attenuation values offer less certainty as to distance. For example, attenuation values in the 50-70 dB range (in this experiment) could result in some instances from devices that are up to 15 meters apart.

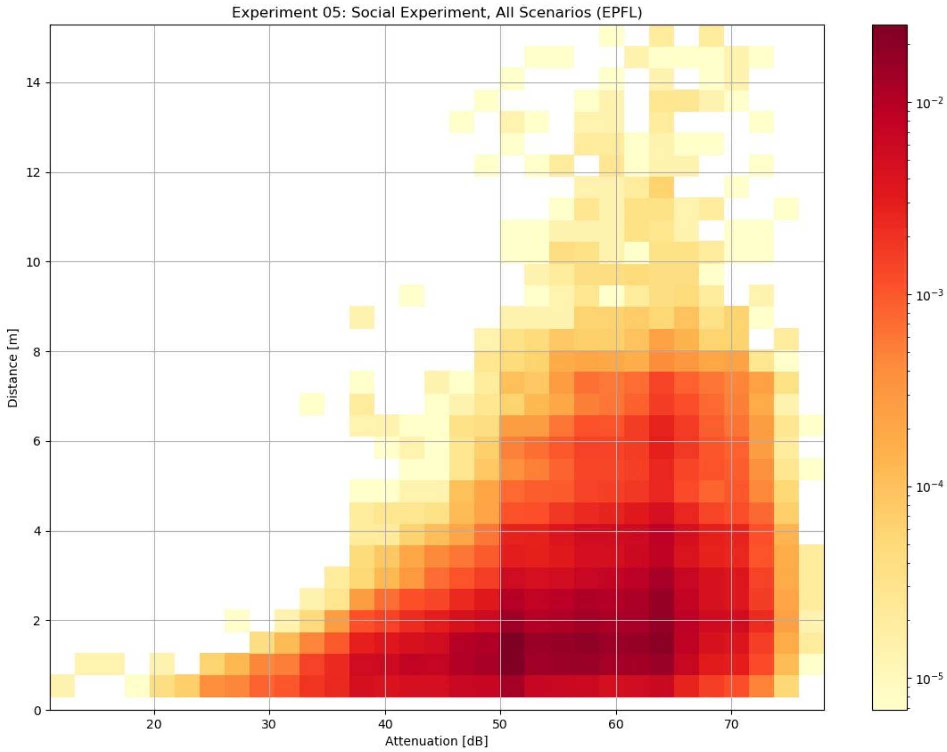

Figure 1. Heat map displaying the signal attenuation and physical distance between two smartphones. Each square represents the number of signals received at an attenuation-distance pair (red is more frequent).

We do not attempt to use the attenuation values to precisely measure distances between devices. Considerable prior work has demonstrated that distance estimation is challenging in diverse environments especially at the BLE frequency of 2.4GHz. Moreover, distance measurement is not the problem that needs to be solved for contact tracing.

The epidemiologically problem is to detect approximate proximity (within a few meters). From this perspective, it does not matter if the devices are 1m or 2m apart. Nor is high measurement accuracy required. The risk of exposure does not abruptly end at 2m, so the difference between 2 and 2.2m is not significant in this context. Instead of precise distance estimation, we therefore study which attenuation thresholds both indicate that the devices are within a given distance and capture the majority of the devices that are within that distance -- the concepts of precision and recall.

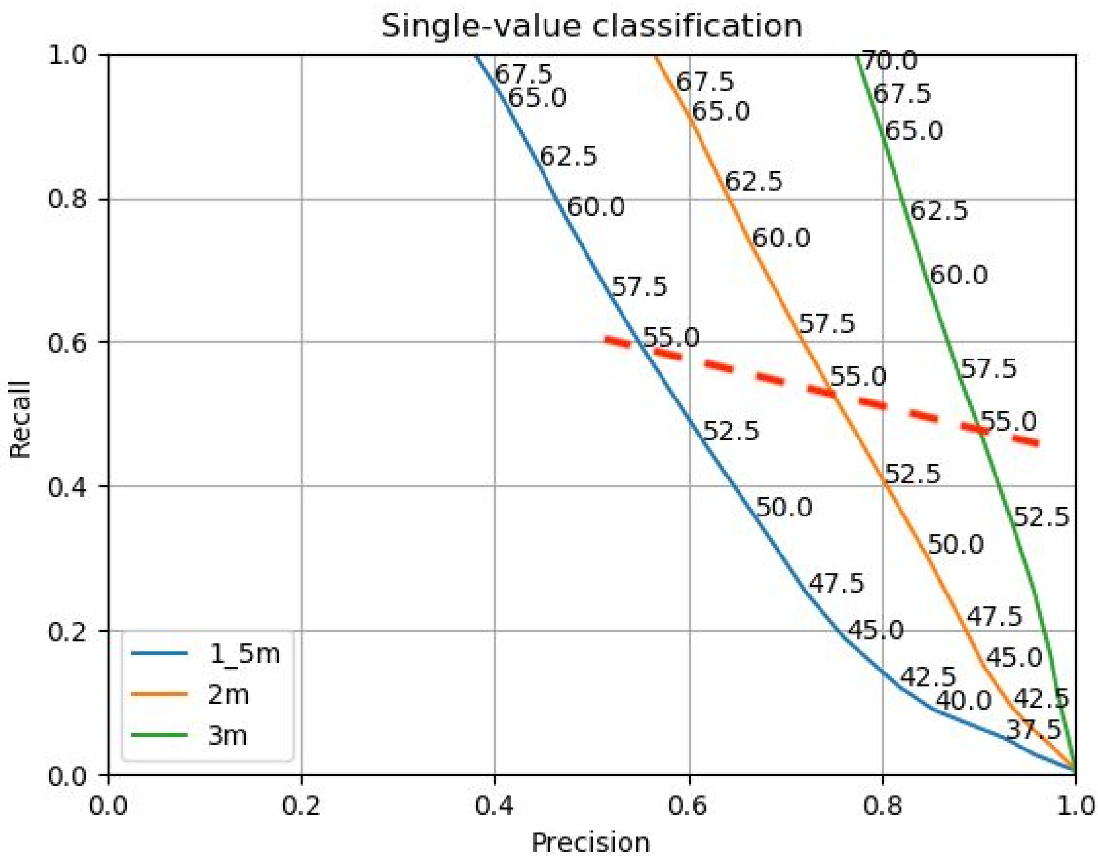

Figure 2. Precision and recall from experiments at three distances. The numbers along the curves are the attenuation values in dB.

Figure 2 shows the precision and recall for estimates that a user is closer than a given distance. These curves were generated from the data in Figure1.[2]

We used the attenuation as a threshold to estimate whether two devices are within a given distance (e.g., the blue line estimates if two phones are separated by 1.5m or less). The numbers along the curves are the attenuation values, in dB, corresponding to the thresholds based on which precision-recall is calculated. Precision is the fraction of beacons for which an attenuation threshold correctly identified that the phone was within a given distance. Recall is the fraction of beacons from phones within that distance that had attenuation equal or smaller than the threshold. For example, on the blue curve (1.5m), around 55% of the beacons with an

[2] Precision vs. recall curves require a statistical distribution of distances. For this experiment, we used the empirical distribution of distances between pairs of individuals acting in a variety of social situations, derived from our experiments.

attenuation level of 55 dB or less came from the phones that were within 1.5m, and 60% of the beacons from phones that were physically within 1.5m were attenuated by 55dB or less (i.e., precision≈0.55, recall≈0.6). For the same 55dB threshold, the precision at 2m and 3m increases to around 0.75 and 0.9, respectively (highlighted by the red dotted line). This means that most of the beacons that were received with attenuation below 55dB and that did not originate from within 1.5m, came from devices that were between 1.5m and 3m away.

We can use these precision-recall curves to select the attenuation values for the SwissCOVID app. To achieve a high precision, we need to be selective and set the attenuation to a low level. However, at that level, many, if not most, of the beacons will suffer higher attenuation and be rejected. By selecting a suitable attenuation level, we can correctly identify a sizable majority of beacons corresponding to a given distance and only incorrectly reject a few. This tradeoff between correctness and inclusivity is shared by manual contact tracing, where a human must evaluate a verbal description to decide if two people were within the given distance.

Estimating exposure using the Google/Apple Exposure Notification API

Apps built on the Google Apple Exposure Notification (GAEN) API periodically check for exposure information of COVID-positive users. The current Google/Apple EN (GAEN) implementation exchanges beacons with neighboring devices every 2.5 - 5 minutes (Figure 3). A received beacon can be interpreted as an indication of proximity for the few minute-wide interval, and its attenuation level gives the probability of being within a certain distance of the device emitting the beacon. The receiver uses the attenuation level to estimate the likelihood of being exposed to the broadcasting device during the scanning window.

GAEN Exposure score

GAEN does not provide attenuation values to an application. The API instead allows the app to request duration of “exposure” to COVID-19 positive people using the ExposureSummary API**.** This 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 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 a maximum of 30 minutes.

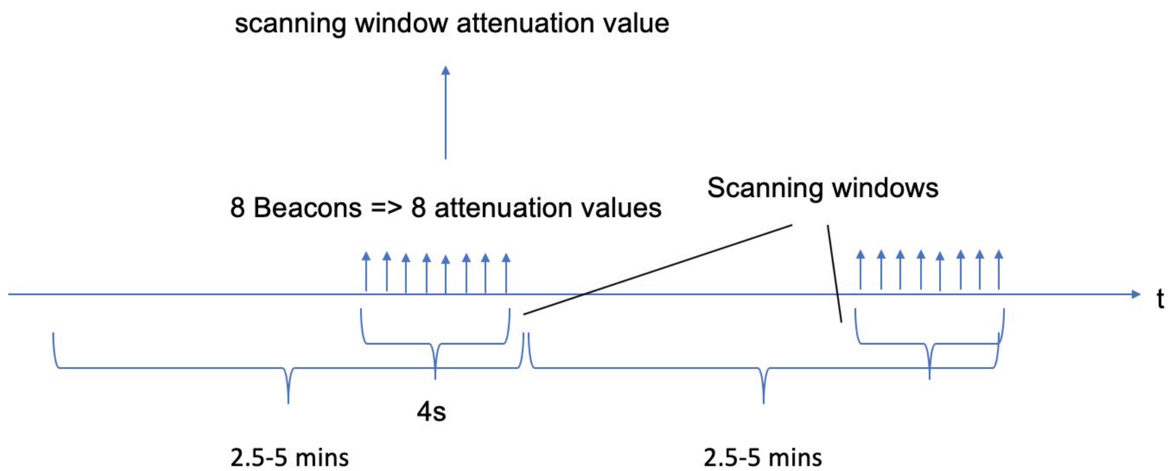

Figure 3. GAEN broadcast of EN beacons. Smartphones broadcast GAEN beacons every ½ second. The phones also listen for and record beacons from neighboring phones every 2.5-5 minutes.

SwissCovid configuration

In Switzerland, 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 (Ordinance of 6/24/20 of the Swiss Federal Council). The Annex of the Ordinance specifies a threshold distance of 1.5m, which is lower than the 2m threshold established by the ECDC.

In the SwissCovid app, this exposure check occurs several times a day and utilizes exposures from the current day and the 9 immediately preceding days. The information from the 9 preceding days should capture the vast majority of contacts with positive cases.[3]

The SwissCovid app uses the GAEN ExposureSummary API to retrieve the duration of exposure of a user to COVID-19 positive people within one day, for each of the three attenuation buckets. The Exposure Score (ES) is an estimate of the duration of exposure at close 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.

[3] 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.

SwissCovid is configured with the following settings :

t1=55dB, t2=63dB, w1=1, w2=0.5, w3=0.

Setting w3 to 0 discards exposures in the third bucket, as they correspond to large attenuation values and likely to large distances between devices. Attenuations in the middle bucket correspond to likely close exposures and are given half-weight (w2=0.5) to contribute to the overall score. Attenuations in the first bucket correspond to likely close exposures and are given full weight (w1=1).

ES >= 15 minutes over a calendar day

This is computed for each day for the current and past 9 days. The exposure notification to the user is triggered if ES is greater or equal to 15min within any of these days.

SwissCovid launched on June 25 with conservative settings of t1=50dB and t2=55dB. The thresholds were first updated on July 06 to t1=53dB and t2=60dB to increase the recall. These thresholds and weights were chosen to balance the precision and recall of exposure notification across a wide range of environments, including home, public transports, office, and public spaces. The current thresholds of t1=55dB and t2=63dB were last updated on September 11, 2020 at the request of FOPH after 2 months of field experience. As Figure 1 and 2 illustrate, these attenuation values empirically correspond with high probability to close proximity.

The Table below provides the full precision-recall empirical probabilities for different maximum attenuations. The selected first threshold of 55dB results in a 56% precision within 1.5m with a 60% recall, and a precision of 75% within 2m. The selected second threshold of 63dB - associated with half-weight - has a precision of 82% within 3m.

	1.5m		2m		3m	
att_thr	**precision**	**recall**	**precision**	**recall**	**precision**	**recall**
50	**0.668**	0.359	**0.846**	0.305	**0.958**	0.252
51	**0.645**	0.403	**0.826**	0.347	**0.948**	0.291
52	**0.616**	0.462	**0.803**	0.405	**0.936**	0.345
53	**0.593**	0.509	**0.783**	0.452	**0.925**	0.389
54	**0.576**	0.542	**0.768**	0.485	**0.916**	0.423
55	**0.552**	0.593	**0.745**	0.538	**0.902**	0.476
56	**0.54**	0.622	**0.733**	0.568	**0.894**	0.506
57	**0.52**	0.663	**0.714**	0.612	**0.881**	0.551
58	**0.502**	0.705	**0.696**	0.657	**0.868**	0.599
59	**0.486**	0.742	**0.68**	0.697	**0.858**	0.642
60	**0.473**	0.774	**0.666**	0.732	**0.848**	0.68
61	**0.455**	0.821	**0.647**	0.784	**0.835**	0.738
62	**0.446**	0.844	**0.638**	0.811	**0.828**	0.768
63	**0.433**	0.876	**0.624**	0.848	**0.818**	0.812
64	**0.421**	0.905	**0.611**	0.882	**0.808**	0.852
65	**0.414**	0.925	**0.603**	0.907	**0.803**	0.88