Testing and validation of the tracing solution 05.05.2020

The validation of the tracing solution has been done in several phases using the data collected from March 27 till April 17 by app testers (around 300 app users throughout the testing period). In particular, the focus of the validation phase:

1. Estimation of the beacon proximity / distance based on the Bluetooth signal strength
2. Evaluation of the phone discoverability via Bluetooth
3. Evaluation of the tracing algorithms for different types of activities such as walking, driving, staying inside, taking public transport, and functionalities such as points of interest, mode of transport, duration inside / outside.

Estimation of the beacon proximity / distance based on the Bluetooth signal strength

We performed controlled experiments for identifying beacon proximity from the Bluetooth signal strength. In particular, we considered the following scenarios:

1. Two phones placed one meter apart from each other for a period of 10 minutes.
2. The phones are in the same room within 2 meters from each other.
3. The phones are in separate rooms.
4. The phones are close to each other in a moving setting (e.g. in the same car, in pockets of people walking next to each other).

The experiments were conducted for both iOS and Android devices, using different phone models and operating systems. For iOS devices, the app was running in the foreground, whereas for Android devices the app was running in the background / foreground.
In total, 18 iPhones were used in the testing (iPhone 11, 11., 12.2, 8, 8+, 10.5, 7+, 9.3, 10) and 11 Android phones (Samsung S5, S8, S8+, S9, Pixel-3, LG Nexus, Huawei Nexus).

Summary results: We have calibrated both iOS and Android devices in order to provide a robust mapping between signal strength and distance while accounting for various environmental factors. As a final product we map RSSI values into three ranges: very close within 1m, close within 2m and relatively close that is between 2 and 5 meters. We have also derived an algorithm for inferring contacts between phones in proximity that do not observe each other due to various technical limitations. This algorithm attempts to answer the following question, if phone A is close to phones B and C, are B and C close to each other?

Evaluation of the phone discoverability via Bluetooth

We performed controlled experiments to understand the discoverability of the phone models in different scenarios: app in background/foreground, phone is sleeping mode/used, etc. The experiments were conducted in different environments: inside, outside, different public transport modes, also checking GPS data. In each experiment, between 3 and 8 phones took part, type of phones and OS tested:

Pixel2, Android 10
Pixel 3, Android 10
S8+, Android 9
Huawei, Android 7
iphone xs , iOS 13
S5, Android 6
Sony, Android 5
iPhone 11, 11., 12.2, 8+, 10.5, 7+, 9.3

The following scenarios were considered:

1. App in background, device is sleeping
2. App in background, device is in use
3. App in background, device locked but not sleeping
4. App in foreground, device is in use
5. App in background and foreground

Environment: inside building; tram, bus and subway journey; walking.

Summary results: As expected iOS are discoverable only when the app runs in foreground, whereas Android devices are discoverable with the app in background and foreground. Moreover, there is a difference in BT discoverability between iPhone models, iOS versions.

Evaluation of the tracing algorithms for different types of activities

We considered different scenarios with given ground truth from different testers to evaluate the performance of the tracing algorithm. In particular, we focus on the following evaluation metrics:

1. Contact identification and duration
2. Identification of points of interest
3. Identification of mode of transport
4. Identification of duration being inside and outside

We considered the following scenarios from different app users:

1. Staying home (5-6 scenarios)
2. Taking a public transport: tram, bus, subway (2 scenarios)
3. Driving (3-4 scenarios)
4. Walking (around 10 scenarios)

5. Jogging (2 scenarios)
6. Biking 1 scenario)
7. Staying in the office (1 scenario)
8. Shopping (2 scenarios)

The activities were analysed from 16 cases that had in total 38 contacts over a one week period using both GPS and BT data. For all cases and scenarios the validation was performed manually.

Summary results: the tracing algorithm is quite accurate in identifying the contact once the data is available, the contact duration can slightly differ from the one reported in ground truth. We observe a larger variability compared to the ground truth in the GPS duration when the contact occurred indoors or while moving fast (driving or using public transport). We had a challenge in finding contacts in the subway due to inaccurate / lack of GPS data, sometimes GPS indoor can be also missing.

The accuracy of GPS is quite low in indoor locations, which makes it more challenging for correct identification of points of interest. Therefore, we incorporated accuracy and frequency in our algorithms to identify points of interest and calculate the duration of contacts that happen indoors.

We observed a lot of short BT contacts, esp. for iOS users. At the same time, GPS data was used to confirm the contact. Specifically, even though the reported GPS distance is usually between 10-20 m, one can conclude that people were together if the duration of GPS contact is longer than a given threshold (we defined it to be 30 minutes).

Note our analysis focused on the performance of the tracing algorithm and correctness of our results rather deriving any conclusions on definition of the “close” contact.

Sample examples from the reports:

Ground truth:
12:00-12:18: walking / waiting on the tram stop
12:18-12:40 - taking a tram
12:40-12:43 - walking towards subway

GPS contact number: 1

Time: 2020-04-13 12:02:31 - 2020-04-13 12:43:45

Duration: 0:41:14

Duration inside: 0:25:32

Duration outside: 0:12:16

Uncertain duration: 0:03:25

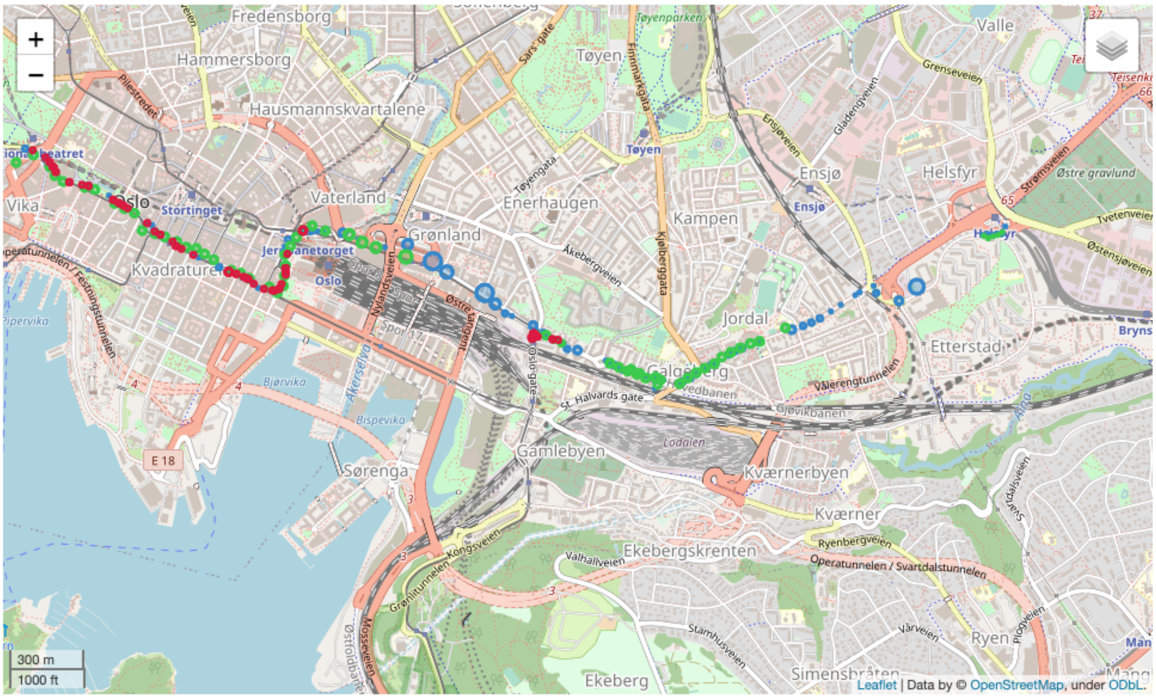
Average distance (accuracy): 28.06 (11.12)

Median distance: 27.26

Transport modes: {('vehicle', 'vehicle'): '0:10:30', ('on_foot', 'still'): '0:08:38', ('on_foot', 'on_foot'): '0:08:42', ('still', 'still'): '0:08:24'}

Points of interest, types of contact: {'outside': '0:12:16', 'inside_transport': '0:09:49', 'other_buildings': '0:14:34'}

Most common transport modes: ['on_foot']



Ground truth:

11:39-12:27: driving

GPS contact number: 8

Time: 2020-04-13 11:38:45 - 2020-04-13 12:20:40

Duration: 0:41:55

Duration inside: 0:14:55

Duration outside: 0:25:45

Uncertain duration: 0:01:14

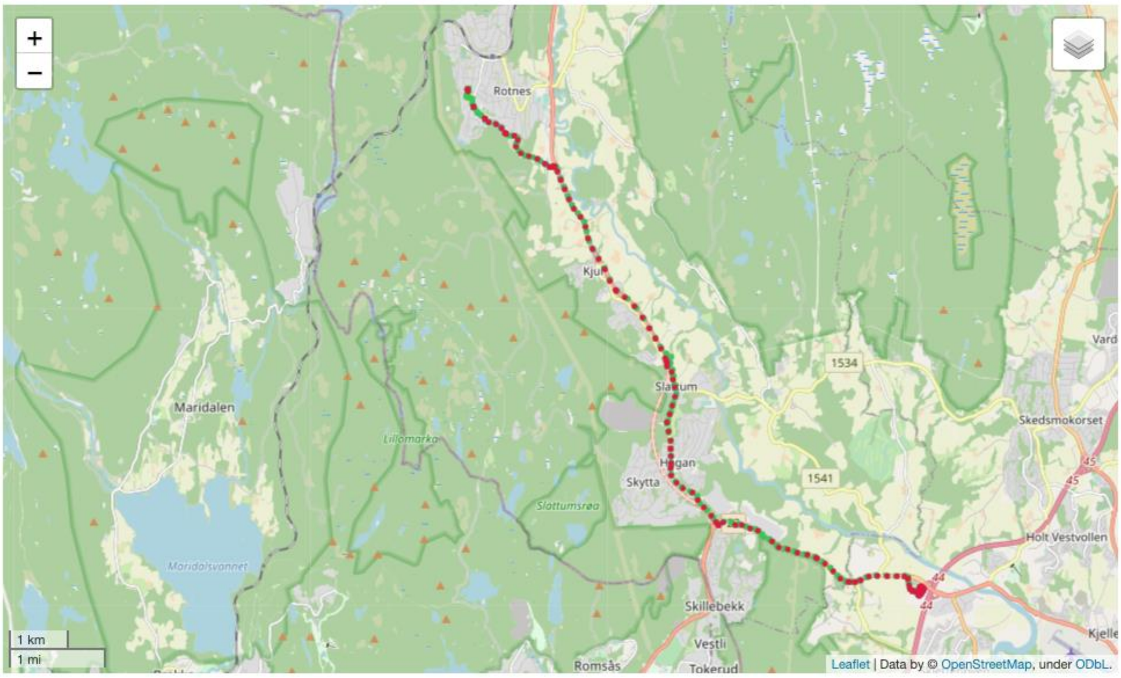
Average distance (accuracy): 13.26 (4.86)

Median distance: 13.86

Transport modes: {('still', 'still'): '0:20:03', ('vehicle', 'vehicle'): '0:15:14'}

Points of interest, types of contact: {'outside': '0:25:45', 'inside_transport': '0:14:23'}

Most common transport modes: ['still']



Ground truth:

10:58-11:10: staying home

GPS contact number: 4

Time: 2020-04-12 10:58:00 - 2020-04-12 11:05:12

Duration: 0:07:12

Duration inside: 0:07:11

Duration outside: 0:00:01

Uncertain duration: 0:00:00

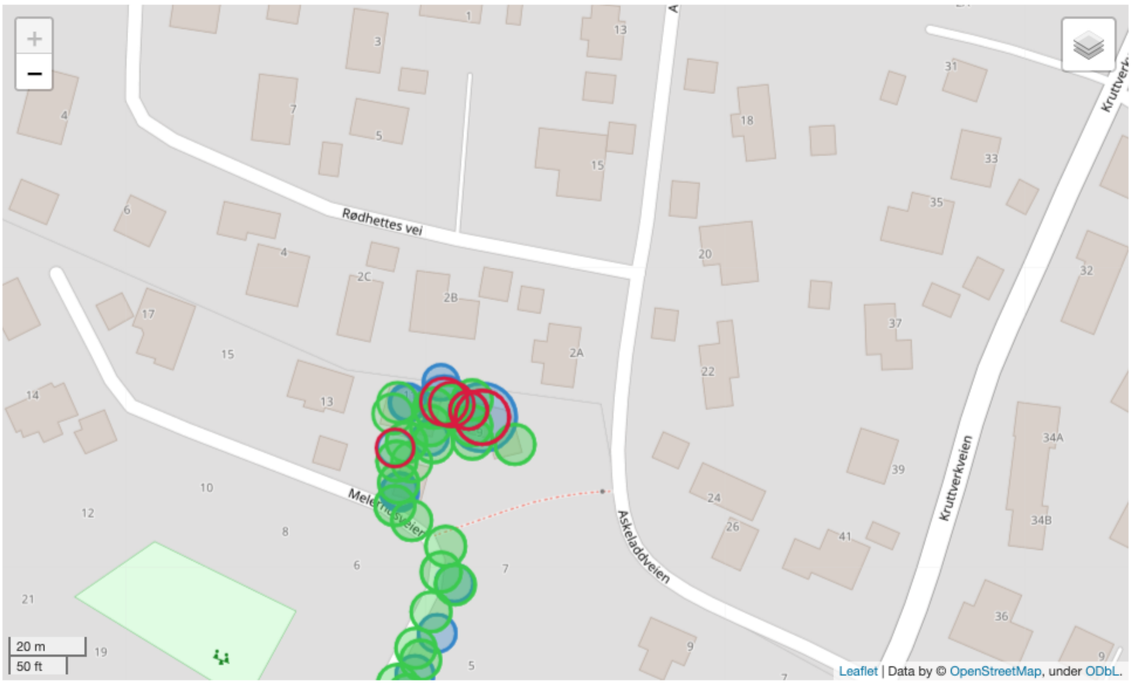
Average distance (accuracy): 7.11 (6.02)

Median distance: 6.95

Transport modes: {('still', 'still'): '0:07:11'}

Points of interest, types of contact: {'residential': '0:07:11'}

Most common transport modes: ['still']



Ground truth:

11:10-11:49: walking

GPS contact number: 5

Time: 2020-04-12 11:11:43 - 2020-04-12 11:41:11

Duration: 0:29:28

Duration inside: 0:01:14

Duration outside: 0:28:14

Uncertain duration: 0:00:00

Average distance (accuracy): 12.75 (4.83)

Median distance: 12.27

Transport modes: {('on_foot', 'on_foot'): '0:26:59'}

Points of interest, types of contact: {'outside': '0:28:14'}

Most common transport modes: ['on_foot']