ClairCity: Citizen-led air pollution reduction in cities

D4.12 Fully functional ClairCity GreenAnt (APP) -LAST CITY

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Document Details

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Description	This document explains the functionalities and target group of the ClairCity GreenAnt system, which is now fully functional for all six ClairCity study cities and regions. The deliverable is the actual system containing the app and web support system, which is now ready for use.

Version History

Version	Updated By	Date	Changes / Comments
V1.0	Mirjam F. Fredriksen (NILU)	02/05/2019	Initial draft
V1.1	Mirjam F. Fredriksen (NILU)	05/05/2019	First version
V1.2	Håvard Vika Røen (NILU)	06/05/2019	Technical review
V1.3	Svein Knudsen (NILU)	08/05/2019	Proofing
V1.4	Mirjam F. Fredriksen (NILU)	08/05/2019	Summary
V1.5	Pål Danielsen (NILU)	09/05/2019	Proofing
V1.6	Mirjam F. Fredriksen (NILU)	10/05/2019	Draft for EMG
V1.7	Svein Knudsen (NILU)	19/06/2019	Final draft
V2.0	Mirjam F. Fredriksen (NILU)	05/12/2019	Update
V2.1	Svein Knudsen (NILU)	06/12/2019	Review
V2.1	Mirjam F. Fredriksen	08/12/2019	Review

V2.1	Svein Knudsen	09/12/2019	Draft for EMG

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Quality Assurance	Irati Artola (Trinomics)
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Executive Summary

The GreenAnt App system is part of the citizens and stakeholder's engagement work (WP4) of ClairCity.

The overall goal of GreenAnt is to provide a service that will motivate people and organizations to change and become more environmentally friendly. The GreenAnt is a large and complex system designed to analyse the contribution to air quality and carbon footprint from individuals, groups of people, such as citizens, industries, service providers and public authorities. The GreenAnt consists of a web tool for initialization, administration and data analysis and a smartphone app for data collection. The GreenAnt app will run on smartphone devices (Android version 6.0 and newer; and iPhone 5 and up) for collecting data within the areas.

The GreenAnt system gives a possibility to undertake a pre- and post-action intervention assessment to actually quantify the changes in citizen behaviour (e.g. travel behaviour) caused by decisions made such as infrastructure changes, parking restrictions, and behaviour change campaigns etc. This gives support to the actual decision/change and a real-time quantification of the effect of the change in activity. It is also the ambition of GreenAnt to empower citizens to adopt new behaviour through awareness of personal contributions to air quality and carbon footprint and indicate how this effects personal health.

GreenAnt uses information from the quantification team in ClairCity (WP5) on city specific air quality background maps and yearly averaged concentration maps scaled by hourly, daily, weekly and monthly adjustment factors for exposure calculation for groups and individuals.

The system is available for all six ClairCity cities/regions namely Bristol, Amsterdam, Ljubljana, Sosnowiec, and the Aveiro and Liguria Regions. GreenAnt will be promoted to the different partner cities through public events and to individual groups. This have been done through flyers, information packages, and exposure on the annual meetings, presentations on workshops and seminars. GreenAnt is developed as a product and will be made commercially available after the ClairCity project has ended.

The core functionality of GreenAnt is not specific to region or city and the system is ready to be used at global scale. The part, which is city specific, is the air pollution exposure information. However, if a city has access to air quality yearly concentration maps, adjustment factors for hour, day, month, it can be easily integrated into the GreenAnt system. The GreenAnt system can also be operated without concentration information, but the output will then be limited.

Fig. 0-1: Google Play and App Store listing

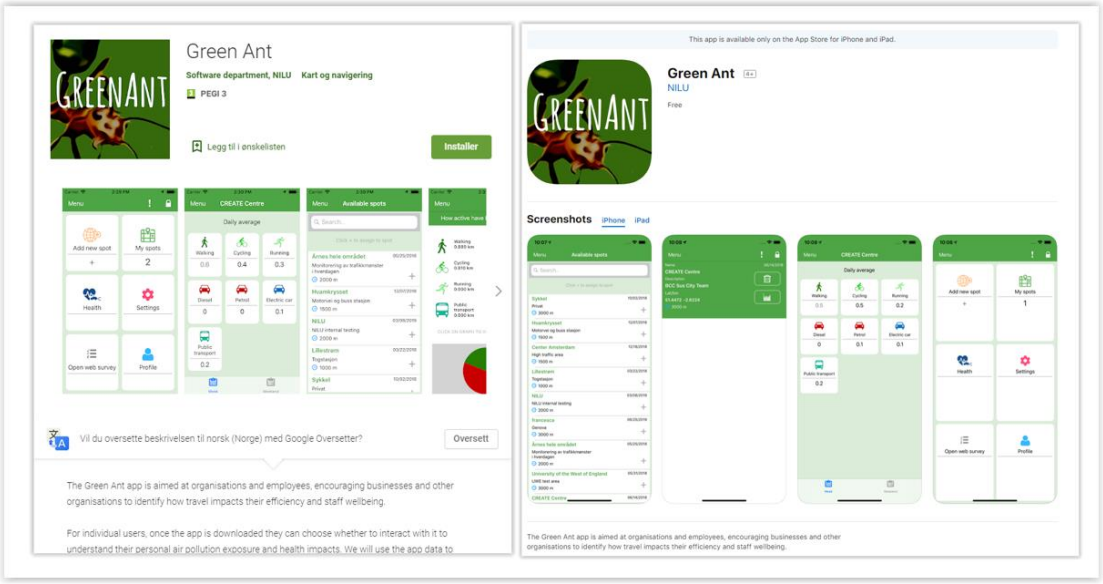
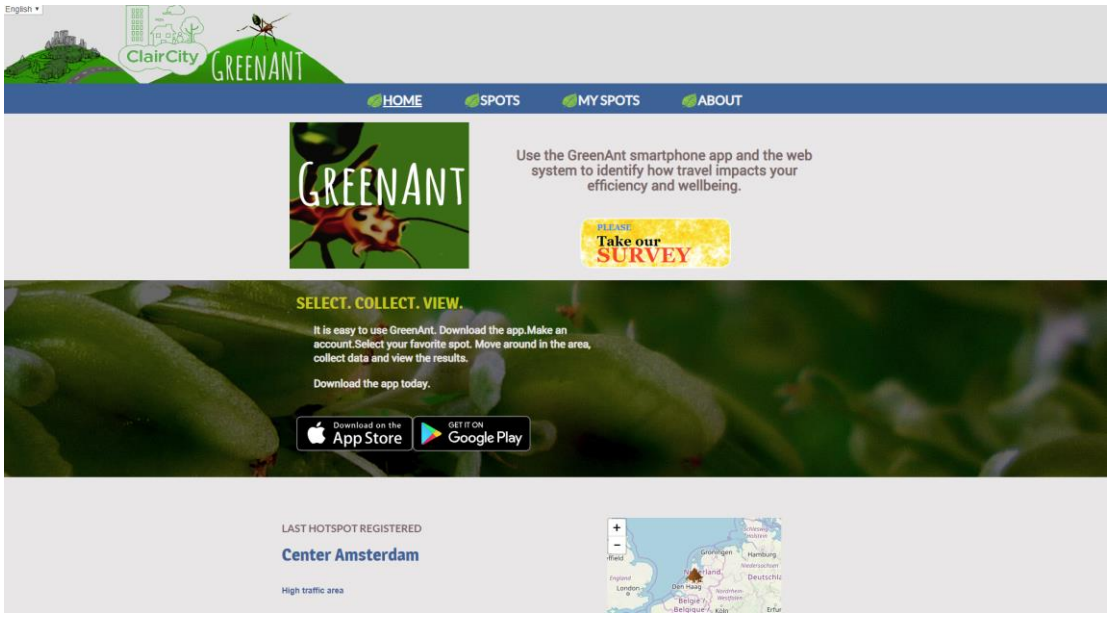


Fig. 0-2: Web tool http://greenant.nilu.no



1 GreenAnt: Behaviour and consequence detection

1.1 GreenAnt Overview

Purpose

Air quality and carbon footprint issues are largely related to people's behaviour and daily activities.

Many projects and solutions in the market have focused on giving users individual information about air quality and carbon footprint. Several apps can be found on both Google Play and iTunes for personal air quality data.

The GreenAnt system takes another approach. **The GreenAnt gives organizations and people data about THEIR activity, THEIR contribution to emissions of pollutants, THEIR carbon footprint and the possible effects on THEIR health. It gives people and organizations the possibility to see the immediately effects of behavioural change, interventions and get insight in daily travel habits and reactions to changes.** Organizations and companies will know what effects they have in their environment.

Use

GreenAnt can be used as follows:

- It can be used to investigate personal contribution to carbon footprint and emissions contributing to local air quality levels.
- The GreenAnt system can also be used by groups of people to map group behavior, for campaigns and trends over longer periods of time. GreenAnt is limited to specific user defined zones for different reasons: to protect the identity of the user, to allow detailed information in a specific area, and to allow analysis of all users and groups of GreenAnt users in the specified zone.
- Government, businesses and large employers can use GreenAnt to investigate the different changes in behavior of users with time. For instance, if a road closes or other infrastructural changes occur, GreenAnt will monitor how the users solve their transport needs and how this influence emissions and give an indication for exposure.
- For industries and service providers the changes to logistics will provide different use of transport and possibilities of greening the business and making the logistics more effective and thereby improve on profit.

Design

The GreenAnt system consists of a web page for analysing the data, administration and creation of user-selected areas and a smartphone application for collecting data inside these areas.

The web page for administration

This gives the users the possibility to register spatially defined areas where they want to collect data about activity patterns, meaning information about activities like walking, cycling, driving and how they are moving around the area and what routes/pathways and travel mode they choose. The web administration page is also the tool where users have access and possibility to process all gathered information together with external data sources like emissions and air pollution exposure.

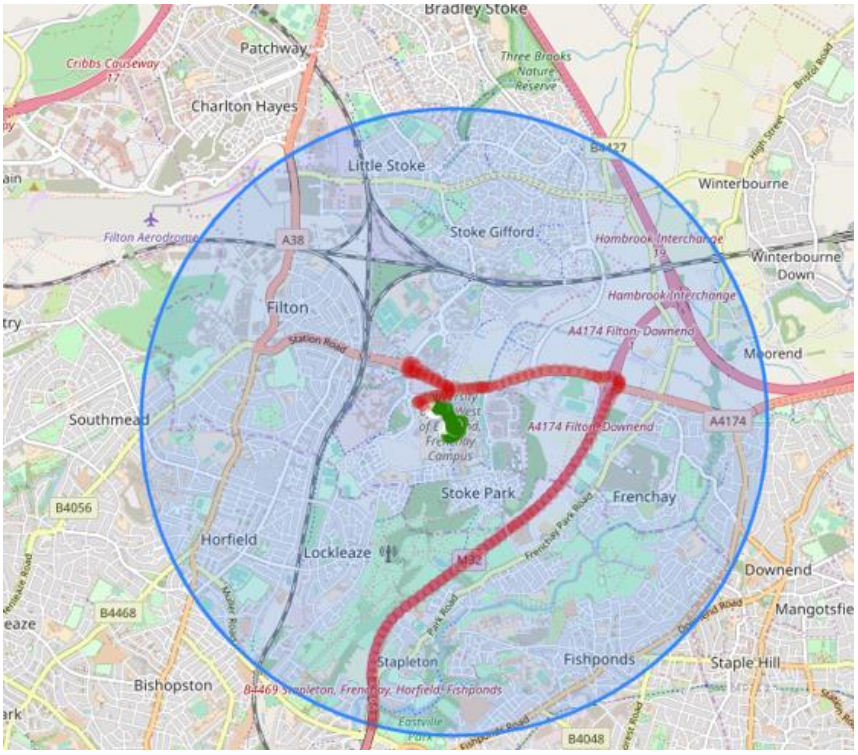
Visualization of the collected data is presented in different ways to give the user a better understanding of what is happening in the area. For example, daily statistics are given to show the total number of people that have been either walking, cycling, running, driving a petrol/diesel/electric car or using public transport. It also gives information about possible

total amount of emissions for this specific area based on the collected information. The collected information will also give an indication of users' total exposure to the air pollution NO_2, PM_{10} and $PM_{2.5}$ on a specific day, in addition to indications about possible health effects.

The administration tool offers a way to compare multiple dates. This gives the user an insight in the group's behaviour, total exposure and variation over time, or the group's reaction (increase or decrease of emissions and exposure) to changes like road constructions, closing of parking lots, weather conditions etc.

In addition to the daily statistics and the possibility to compare days, the web administration tool offers a map simulation option. The web tool displays activity of users for a specific day, starting from the morning and show the activity and the activity type within the area during the day. This gives the user a good understanding of the group's travel patterns during different times of the day.

Fig. 1.1-1: Simulation of travel behaviour from people during a day



A larger plotting option is also available for the travel patterns and activity types, giving the user a possibility to visualize on a map the routes that users choose to drive or walk.

The area administrator can also assign an informative text to the area that will be given to the users when they enter the zone.

The smartphone application

Using the GreenAnt smartphone application, the user can choose to join an area and sign up for collecting data. When a user signs up and accepts data collecting for an area, the data will be collected when the user is within the zone. The user is notified when entering the area if the smartphone application is not running.

There are no restrictions in how many areas a user can be assigned to, so a user can choose to collect data for multiple areas. The smartphone application will also give users daily, weekly and monthly statistics about activity, emissions and pollution expose for each individual area and a summarized statistic.

Fig. 1.1-2: Spots/areas

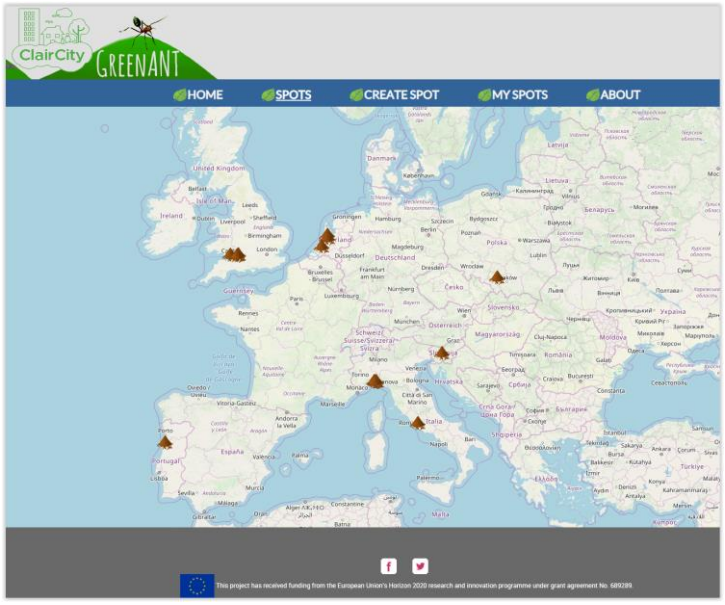
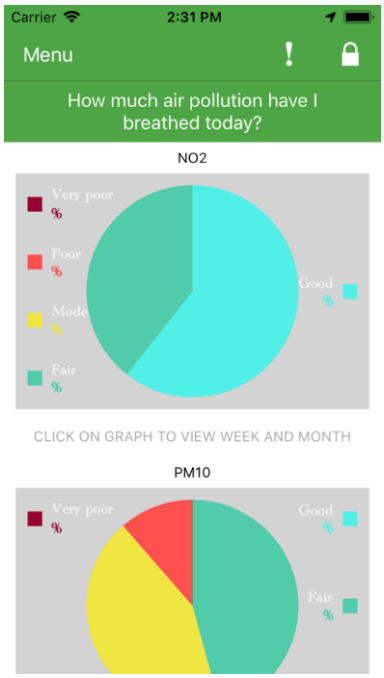


Fig. 1.1-3: Daily statistics



How to use GreenAnt

A complete and updated user manual can be found at http://greenant.nilu.no/GetStarted and in Deliverable D4.13: User manual for app and data report.

Registering an area for collecting data

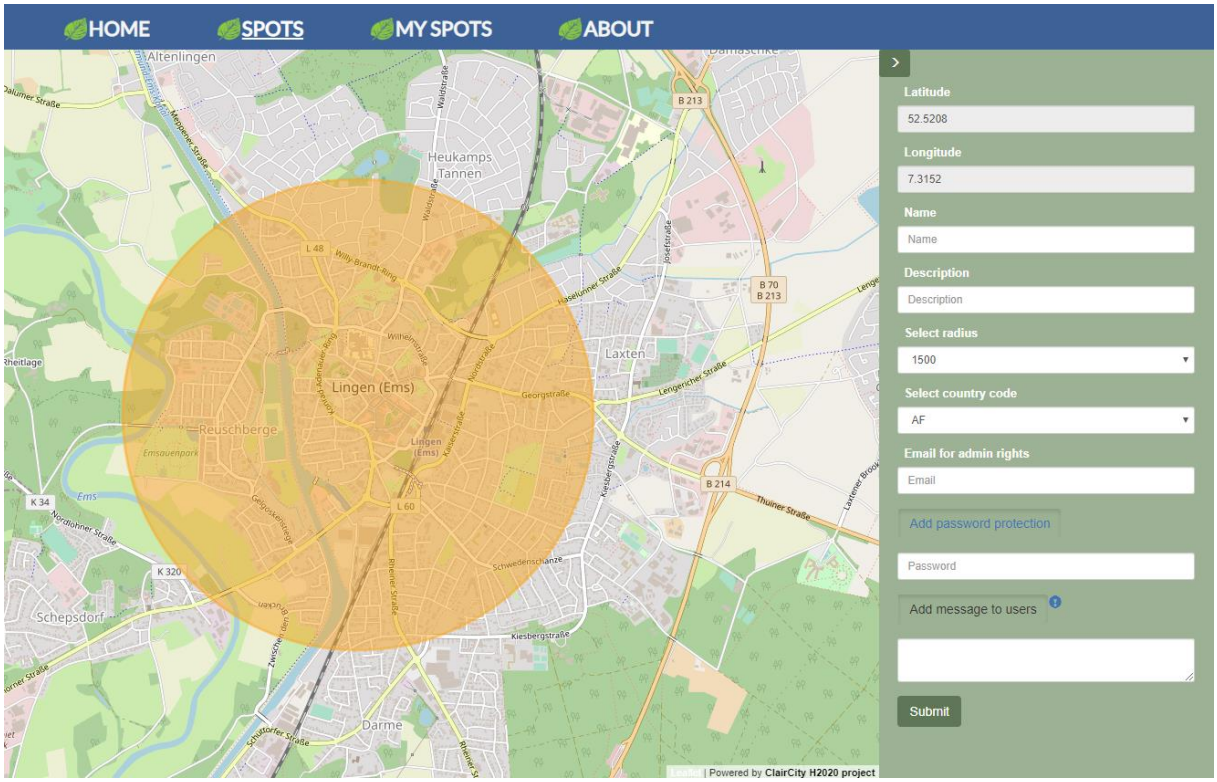
http://greenant.nilu.no

Users can create geographical defined areas (called “Spots”) on the GreenAnt web page. This page translates into preferred language by using a drop-down list on the upper left corner. To register a new spot the user clicks the “Spots” button on the top menu. This will display a map that shows all already registered spots as small ants’ hills.

The user zooms in and click once in the centre of the area to create a new zone. The default suggestion is an area with a radius of 1500 meters. The area can easily be moved by clicking again on the map, until the user has the correct area to collect data. Before saving the area,

an appropriate name and description is added. The radius can also be extended up to 10000 meters. A selection of a country code will help to connect the data for this area, to other relevant data services like air quality exposure and calculations of car emissions. On registration, the user is asked to assign an email address for administration rights to the area.

Fig. 1.1-4: Spot area registration



A password may be added, the area will be visible on the map, but users need to write the password to be able to see the data and the statistics. It is optional to password protect the collected data for a spot.

It is also possible to include a standard message to the users. This message will pop up on the GreenAnt's smartphone application for those users assigned to this specific area, when they physically enter the area. Due to phone specific technicalities, this message can be delayed by 5-10 minutes.

After pressing the submit button, the area is created, marked blue and will be visible as an ant hill on the map.

Start collecting data using the GreenAnt app

The GreenAnt smartphone application collects data about a person's transportation mode (if the user is cycling, walking, running, driving electric/diesel/petrol car or taking public transport) and paths. This app is downloaded from the http://greenant.nilu.no web page or installed from Google Play store or App Store for iOS.

When opening the app, the users give consent that they are over the age of 16 and accept that they know how we safeguard their privacy and safety. The app needs the device's GPS sensors and motion detection technology.

The user creates a user profile by registering a username and password. This gives the user an option of deleting all its collected data at any time by a simple click (aligned with the EU General Data Protection Regulation, GDPR). The nickname will not be stored together with any collected data, if this is not explicitly chosen under the app's Settings. The default is not to share nickname.

Since neither iOS nor android devices detect specific vehicle type that is used, the app asks the user to select a type they normally use when traveling. This can be petrol, diesel, electric or public transport.

All spots created on greenant.nilu.no is available on the app's "Add new spot". The user scrolls down or use the search function to find spots, selects a spot and click an "Assign this spot" button. The user is now collecting data for this area about travel type (walking, cycling, running and going by vehicle) and travel paths within this area.

Fig. 1.1-5: Main screen

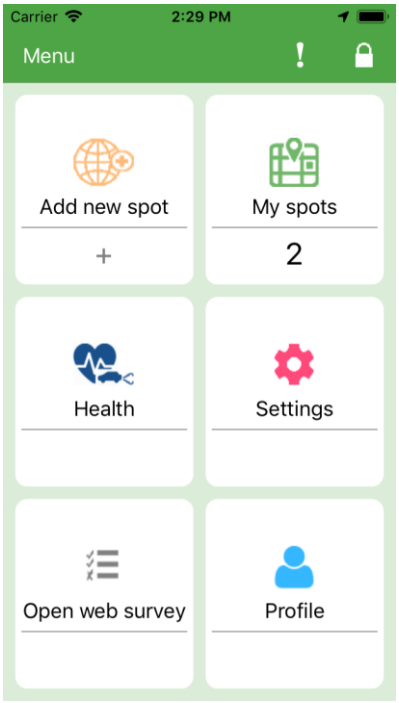


Fig. 1.1-6: User settings

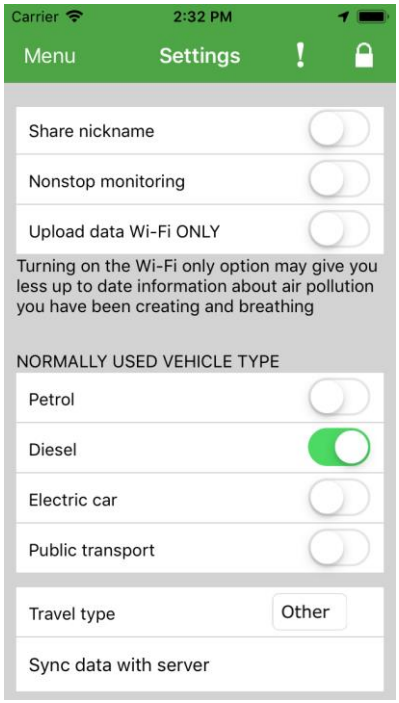
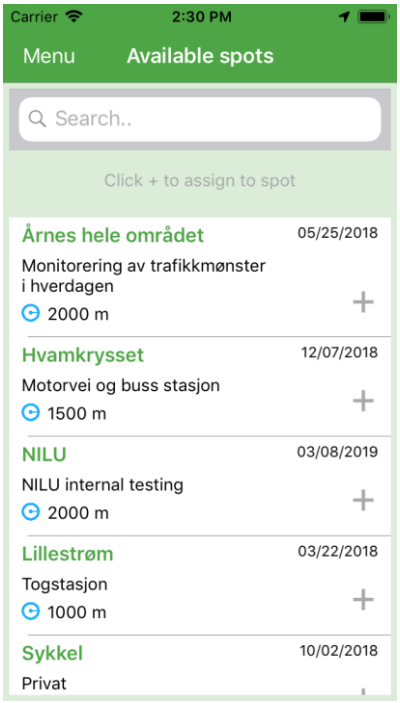


Fig. 1.1-6: Available spots



When the user has started collecting data, the user can view different personal statistics on the app. This includes activity, emissions based on how much she or he has been traveling by diesel or petrol car and look at air quality pollution exposure if available for the city. The statistics are clickable for more detailed graphs and description of data. It is also possible for the user to look at global statistics on the total area.

Fig. 1.1-7: Activity statistics

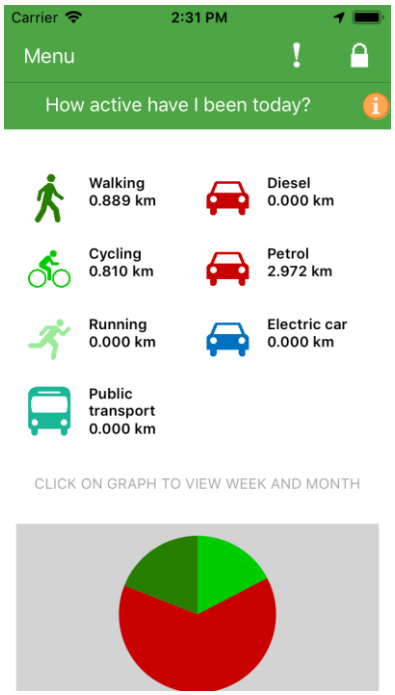


Fig. 1.1-8: Spot statistics

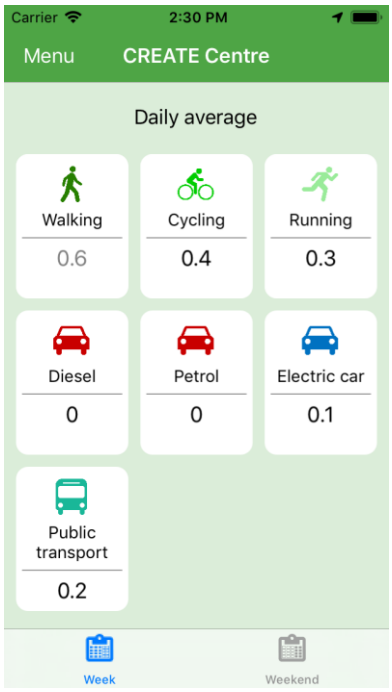


Fig. 1.1-9: Exposure details

GreenAnt security and privacy

The smartphone app is designed to give the user total anonymity while collecting data. The app will not collect any data except what is described in the Privacy & Security section in the app.

Fig. 1.1-10: Privacy

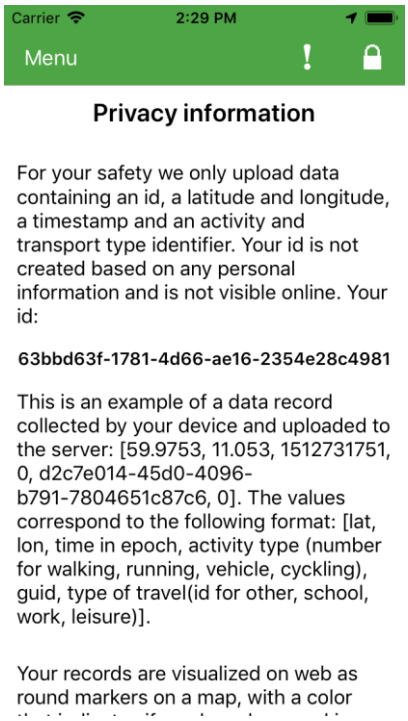
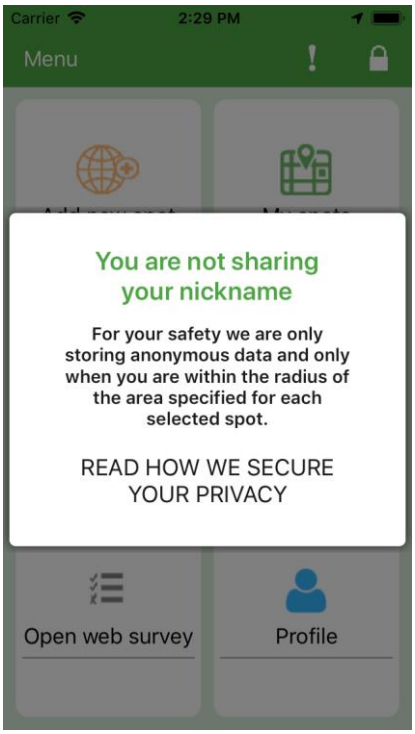


Fig. 1.1-11: Nickname sharing



Analysing collected data

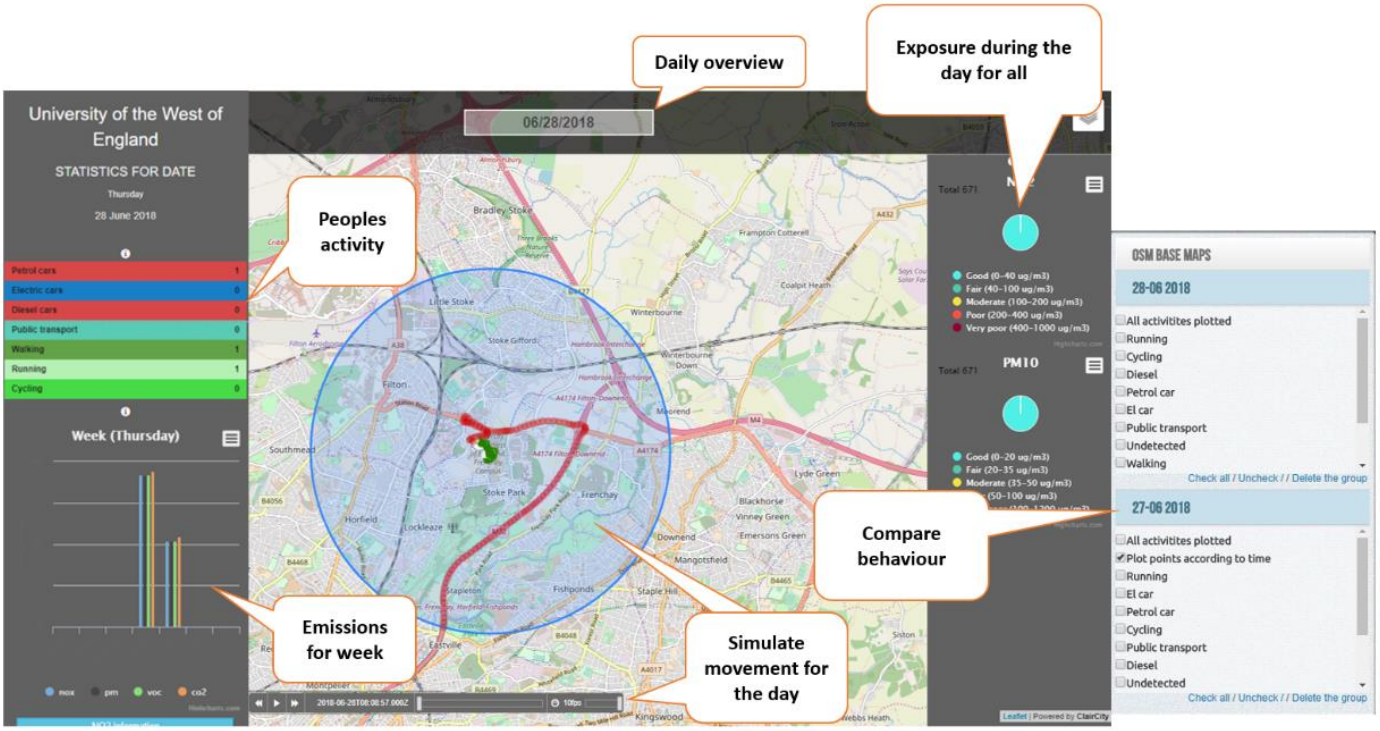


Fig. 1.1 12: Data analyse

The user logs in to greenant.nilu.no portal to view and analyse data collected by app users.

The user selects a date to look at the data. The left side of the page will contain statistics for that specific selected date. It gives information about the number of people who have travelled by car types, public transport and other activity types. It also gives information about emissions. Calculations are based on the country code selected for this spot and is country specific.

Different air quality pollution exposure is displayed on the right side of the screen. These data are calculated based on country and city specific background air quality pollution maps together with calculation adjustment factors for day in year and day of week.

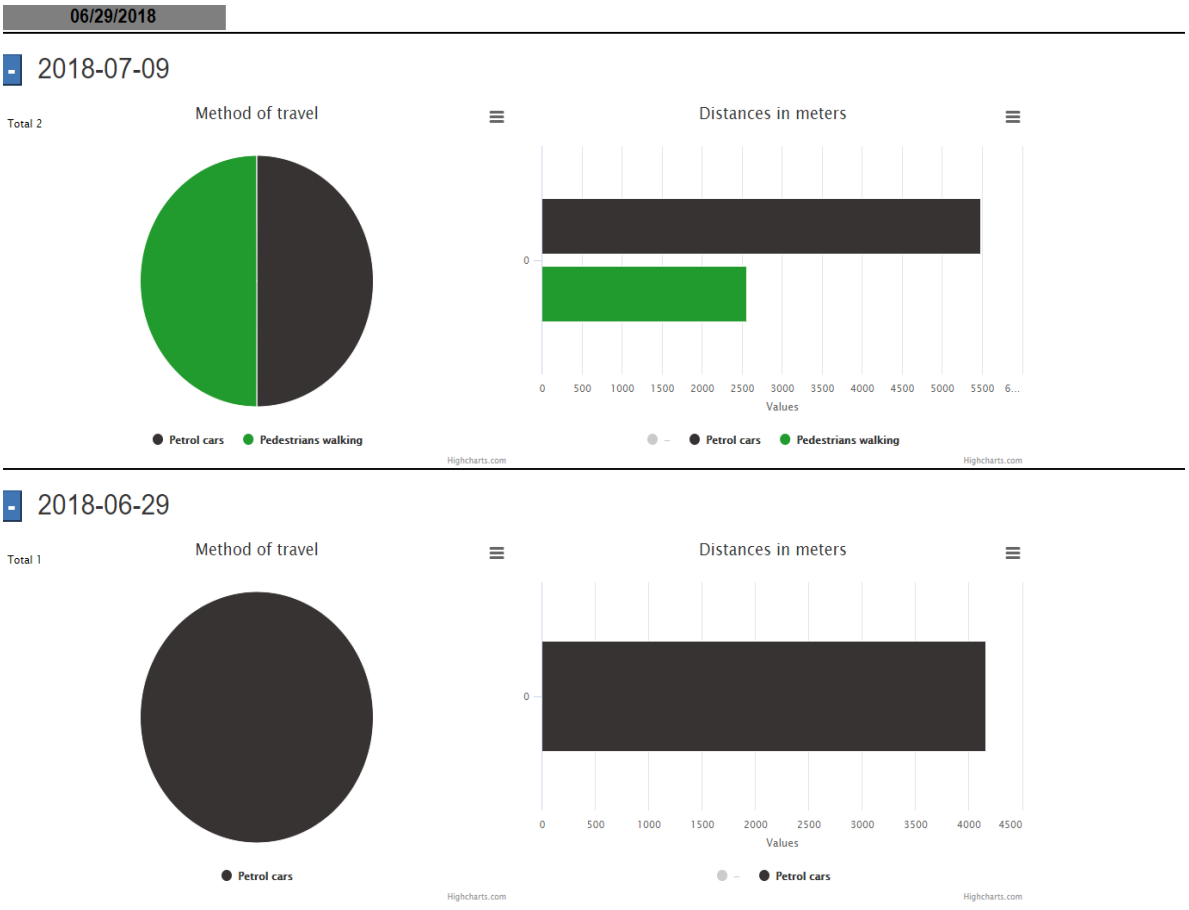
The user can expand the layer option to start plotting data on the map or use the Player to play the activity during the whole day.

Layer options

With the layer tool, the user can plot all activities during a day on the map. The user can distinguish between activity types and plot underlying pollution maps. The user can easily compare different dates by bringing up a new date in the main window. This will automatically be added as a new layer.

The user can also use the Statistics page to compare daily statistics.

Fig. 1.1-13: Data comparison

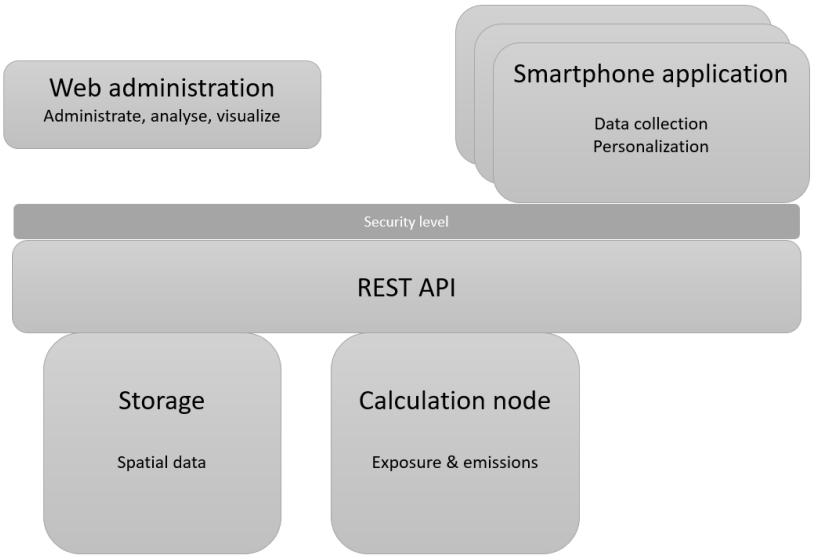


1.2 Technical Design

The GreenAnt system has five main modules:

- a web administration module for areas and zones
- a smartphone application for data collection
- a web API for communication between GUI and database
- a database for spatial objects
- a calculation node for exposure and emissions

Fig. 1.2-1: GreenAnt modules

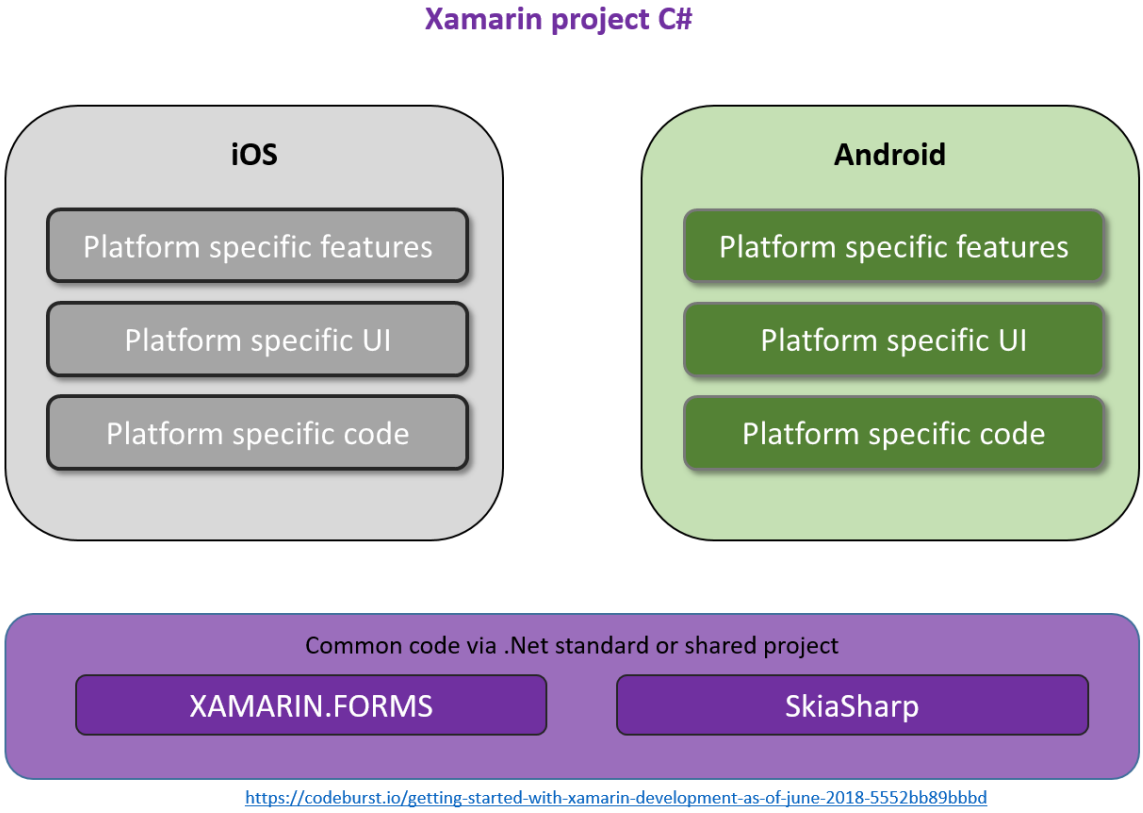


All modules have been developed using Microsoft's .Net platform and Visual studio as IDE (integrated development environment).

The **GreenAnt web** for administration, analysing and visualization of collected data, is developed using Nancyfx, a web framework for .net. Leaflet, java script library for maps, has been implemented for visualizing the data on a map in different layers according to activity or transport type in addition to a calculated NO_2, PM_{10} and $PM_{2.5}$ maps. Leaflet also offers a TimeDimension plugin for playing the data according to time. The bootstrap project provides simple and quick access to front end visual components.

GreenAnt is the name of the **smartphone application.** The app has been developed using Xamarin from Microsoft, which provides tool for cross-platform development and code sharing among the iOS and the android version of the app.

Fig. 1.2-2: Xamarin architecture



https://codeburst.io/getting-started-with-xamarin-development-as-of-june-2018-5552bb89bbbd

SkiaSharp is a cross-platform 2D graphics API for .NET platforms based on Google's Skia Graphics Library.

GreenAnt requires some extra features to be able to detect transportation or activity type. In 2013 Apple started to implement a M7 coprocessor on their devices for better motion detection. GreenAnt requires this to be able to detect if the user is walking, running, driving etc. Therefore, GreenAnt works only on devices from iPhone 5 and up. For android, GreenAnt make use of the google API for activity recognition and therefor requires Google Play service. GreenAnt has been tested for android version 6.0 and newer. The user is prompted to select the most used vehicle type. The built-in library used for android and iOS do not distinguish between the different transportation types. The user can select between electric, petrol or diesel car or public transport. This will be used when activity vehicle is detected.

In addition to the web tool and the app, the GreenAnt system consists of a **web API** (application programming interface) and a **PostGIS database** to store data as spatial objects, making it easier for spatial queries.

Both the web tool and the web API offer password protection for accessing data on a zone. In addition to data collected by the GreenAnt app, the PostGIS database also contains additional data to calculate air quality exposure and estimate emissions. To calculate exposure, we use background maps for each city and factors to adjust for day, week and month provided by Work Package 5. The information in these maps are climatological and

is representative for a normal concentration field, but not intended to be a diagnosis of a specific hour, day or month. The GreenAnt system have the possibility of using on line diagnostic concentrations, but this is not available to the project.

1.3 Future Work & Innovation Legacy

The core functionality of the GreenAnt system can be used by everyone and everywhere regardless of access to air pollution background information. If there are external air quality sources available and in a suitable format, the team can easily integrate this into GreenAnt. This will extend GreenAnt with air quality exposure data in addition to travel behaviour and the general emissions calculations.

A future possible step could be to create a web-based interface for including additional air quality sources.

The team is also looking into the possibility to reuse the data collected to support transport behaviour modelling. A possibility to add a transportation mode (lecture, study, work etc.) has been added to the smartphone application for this purpose after collaboration with WP6.

The GreenAnt system allows the partners of ClairCity project to plan for the continued operation and scaling of the service. In the innovation actions within the project we will plan for this continuation with the ambition of creating a clear innovation legacy. The decisions to be made includes:

- The organization and structure responsible for managing the scale up of GreenAnt
- Prepare and test our business model including structure for sales, distribution and price

GreenAnt has the potential to change behaviour towards more environmentally friendly habits and activities. Our consortium recognizes this potential and aim to implement and position GreenAnt in relevant markets and user groups.

1.4 Lessons learned

This is a simple overview of the feedback from the testing and challenges faced during the development of the GreenAnt smartphone application using .Net and Xamarin for detecting user activity and GPS positions over a longer period, to support sharing of knowledge and lessons to internal and external stakeholders.

Long running services on smartphones

When the project started in April 2016 the development team at NILU already had experience in using people's smartphones for data collection for instance developing software that communicates with low cost sensors with Bluetooth. Creating long running services on a smartphone had been proven to work acceptable on android smartphones. On iOS it was a little more complicated to run processes over longer periods of time without user interactions, but still possible.

In the first development phase of GreenAnt, the core underlying mechanisms of the smartphone app, were developed. This was done to see if it was possible to get data from the smartphone regularly like GPS position and movement type (walking, running etc) and that these services could run for long time periods without user interaction. If this was accepted by the user in several steps, this seemed to work.

However, during every new test on new versions/updates of iOS and Android, or even updates on the manufactories' OS itself, it became more and more problematic to be allowed to have any services running on the phone for a long time. This went against the primary goal of the app which was that as long as the user accepted it and was aware of it, the GreenAnt app would collect data and the user did not have to remember to open the app or do anything to keep collecting data. A lot of effort was put into creating a stable and working core of the GreenAnt for every new update of operation system (Android and iOS) and tested against several device vendors like HUWAEI, SAMSUNG, NEXUS

Unfortunately, it seems like the future development of the smartphone operating system is going further in this direction. A quick search for "don't kill my app" currently have over 200 million hits on Google and Bing. And the web site https://dontkillmyapp.com/ that rates Android vendors that breaks most apps has about 10 000 views every day.

Other challenges

Issues:

1. Mobile OS sets the app/services/event listeners in different mode to free up memory or save battery usage, and it is hard to have control over when this happens. (shutdown, suspended, inactive, background)
2. Huge differences between simulators and real-life use
3. Not able to get access to all app resources/code parts/handlers/sensors when app is not in active mode
4. GPS is drifting when mobile device is indoor – the best way seems to be doing this on the database side to clean unlikely data
5. Some mobile manufactures' OS using android (like SAMSUNG, HUAWEI) sets the app automatically in a list of apps that can be shut down for power saving

iOS

What we did to get the iOS app to run in background for as long as possible without being suspended:

- The app is using CLCircularRegion to only collect motion and gps within specific areas and is assigned to RegionEntered and RegionLeft events
- When app starts:
    - Register location manager (1) with low accuracy, long distance and assign to LocationUpdated event, these are the settings that worked best for us:

```
mng.DesiredAccuracy = CLLocation.AccuracyThreeKilometers;
mng.DistanceFilter = CLLocationDistance.MaxDistance;

mng.ActivityType = CLActivityType.Fitness;
```

```
mng.PausesLocationUpdatesAutomatically = false;
```

- Register location manager(2) for significant location change and assign to LocationUpdated event
- Register location manager(3) for monitor regions and assign to RegionEntered and RegionLeft events

If the app receives a significant location change, this manager will reset some configurations of the location manager 1. This seems to help increase the stability of the location update manager and keep it from “sleeping” or being set aside by the iOS.

If RegionEntered is called but the app was terminated, the app is not allowed to start gps monitoring. Therefor an alert message is displayed to the user to open the app. When the app is in foreground it is allowed to start location monitoring

- AppDelegate.cs FinishedLaunching():

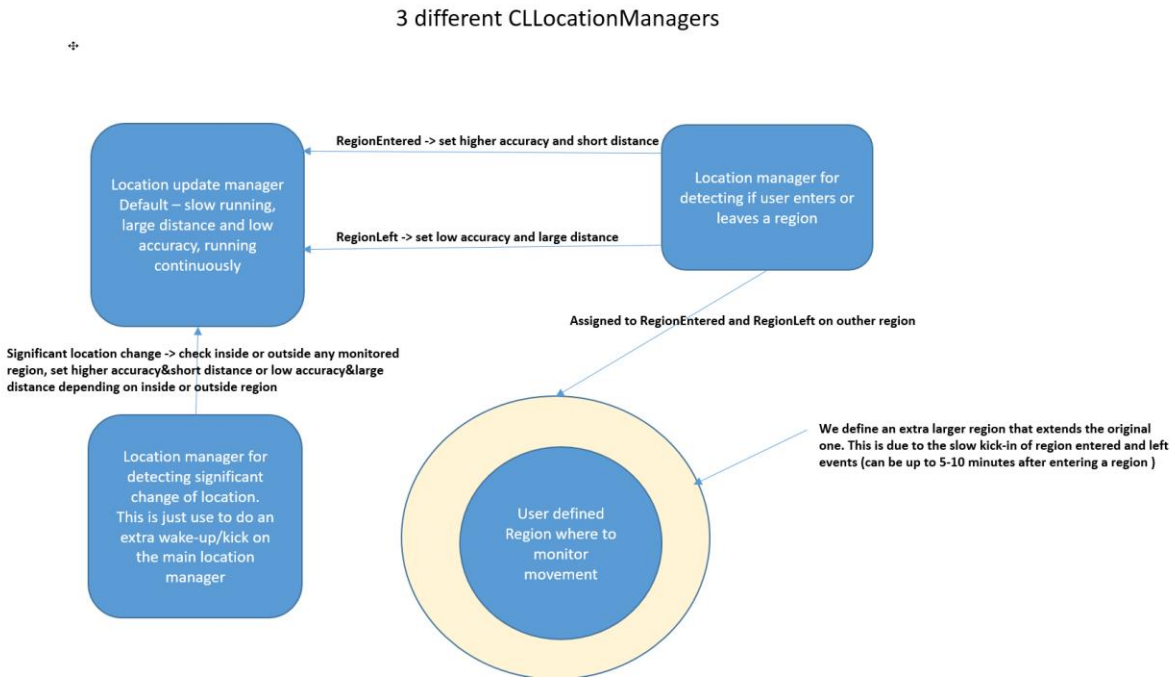
```
//The presence of this key indicates that the app was launched in response to an
incoming location event, in this case region detection
if (options != null && options.ContainsKey(new
NSString("UIApplicationLaunchOptionsLocationKey"))) {
```

The idea is to avoid receiving location update to often when we do not need to. With a higher frequency of receiving updates, IOs will notice that this app uses more battery and memory and is more likely to terminate it.
After some testing, we found that these settings for location manager worked best to get best **GPS for our app inside regions:

```
// From iOS 8 additional permissions requirements
if (UIDevice.CurrentDevice.CheckSystemVersion(8, 0))
{
      mng.RequestAlwaysAuthorization(); // works in background
      mng.RequestWhenInUseAuthorization(); //needed for location notification
 }

// From iOS 9 additional permissions requirements
if (UIDevice.CurrentDevice.CheckSystemVersion(9, 0))
{
      mng.AllowsBackgroundLocationUpdates = true;
}
mng.DesiredAccuracy = 25;
mng.DistanceFilter = 5;
mng.ActivityType = CLActivityType.Fitness;
mng.PausesLocationUpdatesAutomatically = false;
```

Fig. 1.2-2: Overview of roles of the location manager



Android

What we did to get Android app to run in the background for as long as possible without being suspended:

At start-up we register a foreground service, this will add a required notification icon for the service. The service use GeofenceBuilder to only collect motion and GPS within specific areas and is assigned to GeofenceTransitionEnter and GeofenceTransitionExit events.

GeofenceTransitionEnter is too inaccurate for us so we added an AccelerometerListener. This makes a location request whenever the phone is moved and at least a minute since last update.

At start-up we also need to ask for permissions to keep the app alive, there is a permission for White listing of battery (also see this: https://developer.android.com/training/monitoring-device-state/doze-standby - Acceptable use cases for whitelisting)

```
intent = new
Intent(Android.Provider.Settings.ActionRequestIgnoreBatteryOptimizations).SetData(
Android.Net.Uri.Parse("package:" + packageName));
```

In our app we also have an AlarmManager running with inexactrepeating about every 10 minutes (inexactrepeating allows the phone to decide when the task is run to save battery). It queries the fusedlocationapi with prioritylowpower and checks if there is something to upload.

The activity recognition and location tracking for android requires Google Play services. For activity recognition we use Google APIs for Android and for location tracking we use Fused Location Provider API.

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Annex: changes from last version based on Commission's assessment

Comment Commission	How it has been dealt with	Section in report where changes have been made
It is not clear if the ClairCity "Ants" App is working, what are its objectives, who is going to use it, or what could be the potential exploitation. This should be further developed and potentially included in the business and innovation plan.	D4.11 and D4.12 are now synchronized so that the first city Bristol contains the same information and structure as the rest of the Cities/regions. Therefor these deliveries are treated jointly. The objectives are updated. The users are specified. Potential exploitation are defined in D4.11,D4.12 and D4.13 D2.9 describes the development of the business plan	The Deliverable D4.11 and D4.12 are closely related. D4.11 will be equal to D4.12 with the difference that 4.11 is dedicated to Bristol and D4.12 to the rest of the rest of the test partners.
The development of the ClairCity "Ants" App, which apparently is not working.	The GreenAnt system have been working from February 2019.The Smartphone application and the webpage have been available on Google play and iSTORE for downloading from the beginning of 2019. The system has however been lacking concentration data from WP5 to be fully operational. The information on concentrations where not available until early July 2019. There have been several updates of the smartphone operational system. The GreenAnt system have been updated accordingly. D2.13 is describing this process in detail.	
Re-write D4.11 Fully functional App – First City to add details on the App and website objectives, functionalities, target users, etc., and how the outcomes will be input into the project results.	This deliverable at this stage of the project must be seen together with the D4.12. There should be no difference in content between these deliverables. Therefor the two deliverables D4.11 and 4.12 are identical apart from the fact that the D4.11 is dedicated to Bristol and D4.12 dedicated to the other 5 Cities/regions	D4.11 has been tweaked to be consistent with D4.12 and the 6 different cities/regions are now treated equally.

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This reportD(4.11) explains how the App and website tool works. The description of the purpose of using these tools, however, is not totally understandable and would require some revision to increase engagement: “Use the GreenAnt smartphone app and the web system to identify how travel impacts your efficiency and wellbeing” (i.e. which efficiency? In terms of what?). Details are required to be added in terms of the App objectives, target audience, collected data, functionalities, etc.	This deliverable has been synchronized with D4.12	The whole report is rewritten with the knowledge gained up to the deliverable D4.12