



Title: D2.3– Description of Mobile Crowdsensing Mechanisms	Document Version: 1.0
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Project Number: 649849	Project Acronym: ENTROPY	Project Title: Design of an Innovative Energy-Aware IT Ecosystem for Motivating Behavioural Changes Towards the Adoption of Energy Efficient Lifestyles
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Contractual Delivery Date: 30/11/2016	Actual Delivery Date: 30/11/2016	Deliverable Type* - Security**: R – PU
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* Type: P – Prototype, R – Report, D – Demonstrator, O – Other
** Security Class: PU- Public, PP – Restricted to other programme participants (including the Commission), RE – Restricted to a group defined by the consortium (including the Commission), CO – Confidential, only for members of the consortium (including the Commission)

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Abstract:
This deliverable will describe the mobile crowd sensing mechanisms designed for collecting information directly from end users by exploiting the capabilities provided through the use of smart phones and the establishment of social networks.

Keywords:
Mobile crowdsensing mechanisms, social media, mobile applications, open data.

Revision History

The following table describes the main changes done in the document since created.

Revision	Date	Description	Author (Organization)
v0.1	17/10/2016	Table of contents	Norma Zanetti (HYPERBOREA)
v0.2	25/10/2016	Contribution in Sections 2 and 3.	Norma Zanetti, Raffaele Guerriero, Sauro Salvadori (HYPERBOREA), Antonio Skarmeta, Fernando Terroso-Saenz (UMU), Eleni Fotopoulou, Anastasios Zafeiropoulos, Paris Liapis (UBITECH)
v0.3	08/11/2016	Contribution in Section 4.	Antonio Skarmeta, Fernando Terroso-Saenz (UMU)
v0.4	15/11/2016	Contribution in Section 5	Norma Zanetti, Raffaele Guerriero, Sauro Salvadori (HYPERBOREA), Eleni Fotopoulou, Anastasios Zafeiropoulos, Paris Liapis (UBITECH)
v0.5	23/11/2016	Contribution in Section 1, 2, 3 and 6.	Norma Zanetti, Raffaele Guerriero, Sauro Salvadori (HYPERBOREA), M. Pokric (DNET), A. Bousiou (INTELEN)
v0.6	24/11/2016	Version for internal review.	Norma Zanetti, Raffaele Guerriero, Sauro Salvadori (HYPERBOREA)
v0.7	29/11/2016	Internal review comments.	Cleopatra Bardaki (AUEB), Anna Fensel, Umutcan Simsek (UIBK)
v1.0	30/11/2016	Final version.	Norma Zanetti, Raffaele Guerriero, Sauro Salvadori (HYPERBOREA)

Executive Summary

The current document provides the description of the mobile crowd sensing mechanisms that are designed and currently under implementation in the context of ENTROPY project.

Mobile crowdsensing data collection and analysis is considered as an enabler of context awareness support towards the provision of personalised services on one hand, as well as the appropriate interpretation of feedback collected through the end users adopting the ENTROPY solution. Exploitation of the power of the data that can be provided by the crowd in combination with the advanced sensing capabilities of mobile devices is envisaged. In the first category, we also consider data collected and made available as open data in smart cities environments. In ENTROPY platform, a set of crowdsensing mechanisms are going to be supported including participatory and opportunistic crowdsensing and collecting data from mobile applications, social media, sensors owned by end users, as well as available open data. Such data is going to be used for a set of analysis and recommendation purposes, including for instance the composition of the behavioural profile of an end user, the provision of personalised recommendations and the realisation of advanced analysis and comparisons, taking into account available data from relevant case studies.

Table of Contents

- 1. Introduction 5**
- 2. Mobile Crowd Sensing (MCS) Technologies 6**
 - 2.1 Advantages of MCS vs static sensing approaches 6**
 - 2.2 Types of Mobile Crowdsensing approaches..... 7**
 - 2.3 Architecture of Mobile Crowd Sensing solutions..... 7**
 - 2.4 Building Blocks of Crowdsensing 8**
- 3. MCS Approach Adopted By ENTROPY..... 11**
 - 3.1 Overview 11**
 - 3.2 MCS through Entropy Apps 11**
 - 3.3 MCS through Social Media 13**
 - 3.3.1 Particularities of Social-Media Data 13
 - 3.3.2 Entropy MCS approach of Social-Media Data 14
 - 3.4 Entropy MCS Approach of Open Data..... 15**
- 4. Conclusions 18**
- Bibliography 19**

1. INTRODUCTION

Mobile crowdsensing is a technique where a large group of individuals having mobile devices capable of sensing and computing (such as smartphones, tablet computers, wearables) collectively share data and extract information to measure, map, analyze, estimate or infer (predict) any processes of common interest. In short, this means crowdsourcing of sensor data from mobile devices. Based on the type of involvement from the users, mobile crowdsensing can be classified into two types:

- Participatory crowdsensing, where the users voluntarily participate in contributing information [ZHANG2014] [GUO2014b] [GUO2015].
- Opportunistic crowdsensing, where the data is sensed, collected and shared automatically without user intervention and in some cases, even without the user's explicit knowledge [GUO2015].

In ENTROPY platform, both types of crowdsensing are supported. Participatory crowdsensing is based on feedback provided by end users through the ENTROPY personalised applications and serious games. Such feedback may regard identification of problems in equipment or non normal use of the equipment (e.g. air condition open while no people are active in a room), end user actions (e.g. acknowledgement) as well as monitoring of specific parameters via specialised sensors acquired by the end users (e.g. sensors in smartphones).

Opportunistic crowdsensing regards information collected through social media feeds, as well as through end user activities extracted by the daily usage of the personalised applications and serious games. For instance, user acceptance of the provided recommendations, or insights based on daily views of statistics and provided tutorials can provide very helpful information towards the composition of the behavioural profile of the user, aiming at the provision of more meaningful feedback in the future.

Another type of data collection that is also considered as crowdsensing information - however not fully mapped in one of the aforementioned categories- is the data collected via the wide set of open data repositories made available nowadays. Actually, there is currently a trend for convergence of crowdsensing data and open data in smart cities applications. ENTROPY facilitates the consumption of open data since, through the mapping of all the collected data in the ENTROPY semantic models, interoperability and interlinking with available open data can be achieved (e.g. by exploiting linked data principles).

The current manuscript details a set of mobile crowdsensing mechanisms that are designed and actually under implementation within ENTROPY. The structure of the document is as follows:

Section two provides a short analysis of the available mobile crowdsensing technologies along with the description of the approaches adopted within ENTROPY; section three details the set of crowdsensing mechanisms supported by the ENTROPY mobile applications and serious games while, in section four, interoperability and interlinking aspects with available open data sources are presented. Finally, section five provides the conclusions, as well as the way that the developed mechanisms are going to be exploited by WP4 and WP5 towards the release of the integrated ENTROPY platform and the pilots' execution phase.

2. MOBILE CROWD SENSING (MCS) TECHNOLOGIES

2.1 Advantages of MCS vs static sensing approaches

Nowadays, it is possible to sense a huge amount of dynamic parameters of a building in either a direct or indirect way. In this context, we can group the sensed data into two categories, regarding its source:

- To begin with, modern buildings have included, as part of their own infrastructure, new and larger sensors deployments in indoor and out-doors domains. Such deployments usually target specific-purpose solutions comprising static (mote-class) sensors [PAO2014].
- Secondly, the endless improvement of sensing and communication capabilities of personal mobile devices has facilitated Mobile Crowd Sensing (MCS) as a powerful sensing paradigm. By introducing people in the sensing-loop, buildings are provided with alternative solutions that can replace or complement the aforementioned infrastructure-based deployments [NGU2013].

MCS has already proved its feasibility to capture large-scale phenomena in many urban environments, like *road-traffic* [TER2012] or *air-quality monitoring* [ANT2014] that can not be easily captured by solely relying on infrastructure-based sensors [GUO2014]. In that sense, MCS provides two key benefits with respect to traditional deployments based on static mote-class sensors:

- Adopting MCS can reduce deployment costs, since they profit from the sensing capabilities of participant's devices. Thus, it is not necessary to install new sensors in order to capture certain information of a scene [GUO2014].
- Due to the endless enrichment of the sensing capabilities of personal mobile contrivances, MCS provides a general framework to capture a varied range of contextual information. This way, the same MCS solution might be used to sense different parameters of a scenario, like *mobility flows* when the GPS sensor of the participant's devices is used [TER2016] or its *noise map* when the devices' microphones are used [ZHE2014].
- Finally, the usage of personal devices might allow capturing user-related information in more details than if only using mote-class sensors.

Overall, we should regard MCS as a complement of traditional static-sensor deployments in order to capture information from an environment. Moreover, MCS can correct or extend the data gathered by mote-class sensors. For example, [MOR2016] provides a mechanism to locate users in an indoor environment by using an hybrid approach using both infrastructure and mobile sensors.

2.2 Types of Mobile Crowdsensing approaches

In order to interact with the participants of a MCS deployment, it is possible to adopt two different approaches, *opportunistic* and *participatory* [GUO2014], as it is already mentioned in the introductory part of this document.

With **participatory sensing**, the participants/ volunteers opt to meet an application request out of personal or financial interest. A participatory approach incorporates people into significant decision stages of the sensing system, such as deciding what data is shared. Hence, a participatory system design focuses on tools and mechanisms that assist people to share, publish, search, interpret and verify information collected using custodian devices, as well as social technical techniques to encourage the involvement of the public [GAO2014].

With **opportunistic sensing**, participants may not be aware of active applications. Instead, a custodian's device (e.g., smartphone) is utilized whenever its state (e.g., geographic location, body location) matches the requirements of an application. This state is automatically detected; the custodian does not knowingly change the device state for the purpose of meeting the application request. To maintain transparency, opportunistic use of a device should not noticeably impact the normal user experience of the custodian as he uses it for his own needs. Thus, the primary challenges in opportunistic sensing are determining when the state of the sensing device matches the requirements of applications, and sampling when the device state and custodian requirements (i.e., privacy and transparency) are met [TER2016].

In both of the aforementioned categories -participatory sensing and opportunistic sensing- belong also the data collected in smart cities environments and made available as open data in open data repositories. In this case, a hybrid type of crowdsensing data is considered with data used in real time as well as a posteriori, mainly for analysis purposes and comparison case studies.

2.3 Architecture of Mobile Crowd Sensing solutions

In general terms, the architecture of a MCS deployment comprises three different components as depicted in Figure 1.

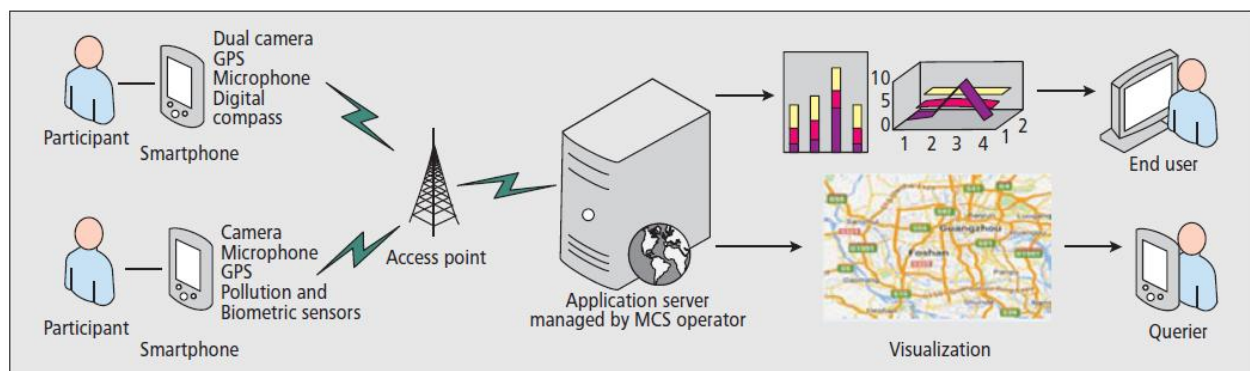


Figure 1. *General architecture of a MCS deployment*¹.

- Firstly, the rightmost side of the figure shows the querier/end-user. This is the entity that uses the MCS system in order to gather useful information about a large-scale phenomenon (e.g. current traffic state of an urban area). To do that, it launches some type of query over the system in order to extract such information. In that sense, it is important to remark that in certain cases the querier and the end-user are not the same person or, at least, there are other end users apart from the querier.
- Secondly, the central element of a MCS is the application server. This element comprises all the logic in order to distribute the sensing tasks required to deal with each new query among the different participants/contributors. For that goal, a task-allocation manager is in charge to carry out fairly distribution of the tasks [BHA2015]. Then, this server is also responsible for aggregating and fusing the sensed data coming from the active participants. In that sense, techniques like compressive sensing are used in order to ensure a high quality of the generated information [WAN2016]
- Finally, the participants of a MCS are the users which actually perform the sensing tasks by means of their personal mobile devices. Depending on the goal, different sensors of the devices will be used. Furthermore, depending on the adopted approach (participatory vs opportunistic) the mobile application running on the participants' devices will require or not the explicit acceptance of the holder to take part of sensing campaign.

2.4 Building Blocks of Crowdsensing

Usually, in crowd-driven eco-systems, the crowd is consists of end-users who participate in their spare-time without any previous training. Consequently, a crowd-driven platform must be very easy to use with a low entrance barrier that creates a clear value for the end-users [ZIO2016].

In general, there are three building blocks of crowd driven IoT solutions (Figure 2):

- Participants – people/crowd/end-users
- Technology – different technical solution enableres
- Business/Economics – business model and economic foundations of the solution

1 <http://bebtechieeepjournals.blogspot.com.es/2015/10/user-privacy-and-data-trustworthiness.html>

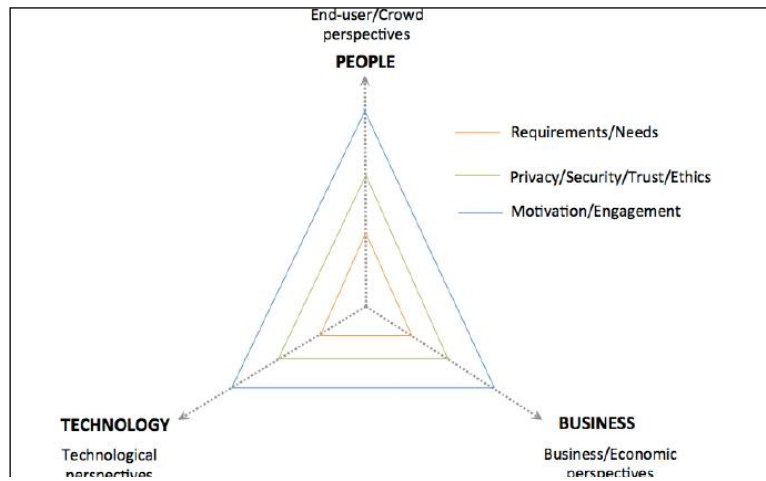


Figure 2. A multi-dimensional model for crowd-driven IoT ecosystems

In summary, (a) the people-centric perspective encompasses the crowd views (b) the business-centric perspective emphasises the creation of economic and business value of a given crowd-driven ecosystem - factors that affect the network sustainability- and (c) the technology centric perspective that focuses on the technological aspects (e.g., ecosystem architecture and components, technological resources, etc.) relevant to the design and development of a crowd-driven network [ZIO2016].

When designing human centric crowdsensing based solutions, the following aspects have to be addressed:

- Participants' requirements/needs
- Privacy/Security/Trust/Ethics
- Participant's motivation to be engaged

Participants' Requirements/Needs

It is essential to identify users' requirements and needs, which will be the main driving factor for ENTROPY applications uptake and retention rate. Users should also be provided with the necessary tools that will ensure both their connectivity as well as their ability to interact and jointly participate at different levels.

To address this important issue, in the context of ENTROPY different aspects of gamification implementations are investigated and assessed by potential users during the design of the personalized apps and serious games.

Privacy/Security/Trust/Ethics

To ensure that end-users want to participate and contribute to crowd-driven ecosystem, it is important that they feel safe and secure, and that their privacy maintains intact when sharing personal data. Therefore, end-users privacy must be protected in two different levels [ZIO2016]:

- (1) Personal data handling - how the personal data (e.g. personal profile) is protected, managed, used and stored in the back-end systems and

- (2) Personal data visualisation - the user interface of the intermediary platform where privacy is related to what is shown about the crowd participants in a public sphere in the platform (e.g user profiles, engagement in tasks, data they have shared)

Hence, types of systems which use crowd-based data should follow privacy-by-design principles that make the users safe and not having to consider all possible threats that they might face by using the system. Thus, individuals should have the power to determine *when, how and to what extent information about them is communicated to others*.

The aforementioned considerations are going to be taken into account during the implementation of the ENTROPY personalised applications and serious games.

Motivation

While ensuring that end-user privacy is protected by the crowd-driven ecosystem, it is equally important to understand what motivates the crowd to achieve the best outcome of crowdsensing. In previous research on crowdsourcing and motivation (e.g. [BRAM2010], [KAUF2011], [NOV2007]), factors such as enjoyment, career concerns, satisfying intellectual interest, increase of status, supporting the community, feeling affiliated and create social contacts have been identified. Research has led to the conclusion that crowds are motivated differently depending on the type of crowdsourcing initiative they are engaged in [STAH2015].

For instance, different types of motivation exist such as:

- contributing to a larger cause;
- possibility to earn money;
- challenges and winning a prize;
- enjoyment, having fun.

Following the different types of motivations, through crowdsensing data collected by the end users, the extraction of their behavioural profile is going to be realised, leading to targeted recommendations with higher acceptance ratio.

3. MCS APPROACH ADOPTED BY ENTROPY

3.1 Overview

In the ENTROPY project, the involvement and the data collection from the participants during the different experiments are two paramount aspects. Thus, the MCS paradigm seems a suitable solution to achieve both goals.

Regarding the particular approach of MCS (participatory vs opportunistic), we should bear in mind that in each ENTROPY deployment within the pilots, contributors are committed to use different mobile applications and serious games installed in their personal devices. Their interaction with such applications and games will generate several types of feedback. In certain situations, this feedback will be explicit from the users (e.g by indicating their actions in a game or clicking a button in a mobile app), whereas in other situations it might be implicit (e.g by moving from a certain room to another).

Consequently, the final approach adopted within the ENTROPY platform will be *a hybrid solution of opportunistic and participatory MCS*. This way, certain data from the users will be sensed from the explicit actions made by the users in the applications, like pressing a certain button of the app, and other data will be gathered in unconscious mode, like obtaining the current GPS location of user.

Concerning the general MCS architecture in ENTROPY platform, we will follow the prescription already mentioned in section 2.3. However, unlike a traditional MCS scenario, the information items sent from the server to the participants will not be queries to collect data, but tips and pieces of advice to be shown in their personal devices. As a result, the different answers and reactions to such items will constitute the sensed data from the participants which will be collected back by the server. Interlinking of collected data with available open data will be also supported.

The following subsections detail the Entropy's MCS approach.

3.2 MCS through Entropy Apps

A set of crowdsensing data is going to be collected through the set of ENTROPY personalised applications and serious games. Such data will include:

- Geolocation data regarding the position of end users at each point of time;
- Demographic data mainly provided during the registration process. Such data may be updated/enriched by the end user;
- Preferences data gathered through the execution of ad hoc surveys;
- Multimedia files associated with a point of interest (e.g. photo from an active device that could be deactivated);

- Mobile sensors' data providing information regarding parameters sensed by the end user device (e.g. luminosity, temperature);
- Insights on the user's perceived comfort level when exposed to different temperature, lighting, noise, CO2 conditions;
- Data from custom equipment of the end user or custom equipment made available in the building (e.g. outdoor weather station);
- Data and analytics collected from the applications and serious games without necessitating the intervention of the end user. Such data is going to be used mostly for building the behavioural profiles of the users (e.g. based on his ranking in terms of energy efficiency, categorization based on their lifestyle, adoption rate of recommendations, gaming progress, engagement status with the app etc).
- Feedback data upon the personalized content delivered to the user (e.g. "Useful tip", "Take quiz", "Take the challenge", "Complete the survey", "Useful news", "Complete the goal" etc.)
- Statistics about users' initiation to motivate other users take action by forwarding them recommendations, challenges and other content
- Social media presence and influence as recorder through users' interaction with social media (connected account, shares, posts etc.)

A special type of mobile participatory crowdsensing mechanism is also going to be applied based on the support from the ENTROPY personalised applications for providing indications regarding the presence of people in the buildings/rooms that they usually have activity. The identification of presence is going to be based on indications provided by the end users through the identification of each room via QR codes (Quick Response Code) or specially made stickers. QR code is the trademark for a type of matrix barcode (or two-dimensional barcode). To scan a QR code, or sticker (i.e. image) the end user will only have to open the ENTROPY mobile application, and point the camera at the code or image. The mobile application is going to automatically recognize any code the camera is pointing at. The only requirement is the existence of a camera on the smartphone that provides the resolution or focus required for barcode scanning or image, characteristic that is considered very common.

Data collection is going to be realised, in most cases, in a real-time based on automated processes or feedback provided by end users, however mechanisms for content provision at any time by the end users will be also made available. The interaction between the MongoDB and the set of personalised applications and serious games is going to be based on a set of APIs, the current version of which is shortly described.

Location awareness is also envisaged to be supported via mobile crowdsensing data based on geolocation data acquisition from mobile applications. Mobile users take their devices with them everywhere, and adding location awareness to personal application will help follow participant movement and potentially can be used for behaviour description. The location APIs available in Google Play services facilitate adding location awareness to the mobile application with

automated location tracking, geofencing, and activity recognition. The Google Play services location APIs are preferred over the Android framework location APIs (`android.location`) as a way of adding location awareness.

There will be also solutions that use WiFi such as iBeacons and Internet connectivity to provide mobile apps with their current location, and enable indoor navigation and wayfinding for Android and iOS platforms².

With regards to environmental data acquisition, the Android platform provides four sensors that let you monitor various environmental properties. Such sensors are going to be used for monitoring the following parameters near an Android-powered device:

- ✓ relative ambient humidity
- ✓ illuminance
- ✓ ambient pressure,
- ✓ and ambient temperature.

All four environment sensors are hardware-based and are available only if a device manufacturer has built them into a device. With the exception of the light sensor, which most device manufacturers use to control screen brightness, environment sensors are not always available on devices. Because of this, it's particularly important that at runtime it is verified whether an environment sensor exists before realising an attempt to acquire data from it.

3.3 MCS through Social Media

Social network sites are now part of our daily life and they generate an unprecedented amount of direct and indirect data about ourselves and the environment around us. In that sense, a novel line of research makes use of different data-mining techniques to generate certain human-related models and patterns [GAO2015, TAN2010].

3.3.1 Particularities of Social-Media Data

Unlike other sources, social-media data tend to be rather noisy since it is usually human-generated. In that sense, we can distinguish two types of data coming from each document (e.g. posts in Facebook, *tweets* in Twitter) shared in a social network:

- Firstly, the content itself of the document like a text, a photo or a combination of both. This is actually the data generated explicitly by the user.
- Secondly, the meta-data associated with the document. This type of data is automatically generated by the social-network site itself to label the document's content with the generation time, the geo-localization and other potential contextual information. This dichotomy is a key difference between social-media feeds and other sources. For example, when it comes to identify mobility patterns, traditional approaches dealt with spatio-temporal data coming from GPS datasets [PEL2014]. Nonetheless, with the advent

² http://public.accuware.com/files/Accuware_Indoor_Navigation_Fact_Sheet.pdf

of social-media data, these spatio-temporal datasets now include textual information that can be processed in order to enrich the extracted mobility patterns with information about the activities performed in the identified points of interest [TER2016-2].

Therefore, in order to fully profit from social-media feeds, solutions must be able to process these two types of data. Furthermore, they also need to deal with the inherent uncertainty and ambiguity of the textual information. These required capabilities are a major difference between social-media data mining solutions and traditional ones.

3.3.2 Entropy MCS approach of Social-Media Data

Due to the key importance of the human-centric sensing in the context of the ENTROPY project, it is necessary to also consider certain information of social-media feeds. In particular, the documents left by the participants of the pilots in the social network sites might provide an extra source of information that can enrich the feedback provided by means of the mobile applications and serious games.

In that sense, the data that we can collect from social networking has certain similarities with the one collected in a MCS deployment. Firstly, the data is highly distributed among a community of participants (in this case, social-network users). Secondly, as a result of this high distribution, it is necessary to perform some type of aggregation procedure over the social-media data in order to extract useful knowledge.

Therefore, we will follow the same logical approach in order to process social-media data than the one for the MCS data. More in detail, Fig. 3 shows the general solution for such a task.

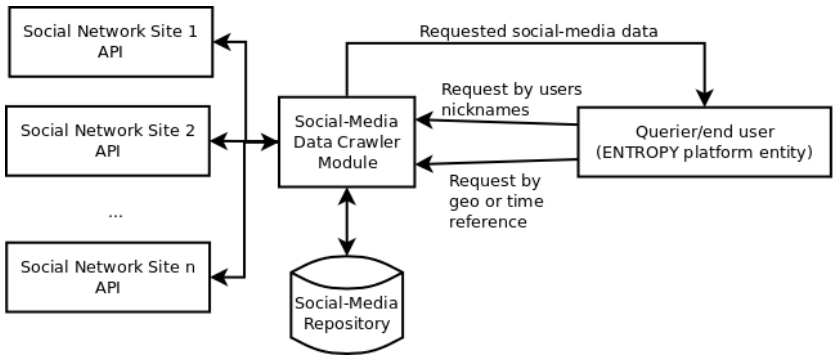


Figure 3. General approach to extract Social-Media data in ENTROPY

As Figure 3 depicts, the solution adopted consists of a central module (Social-Media Data Crawler) that is in charge of processing the different requests coming from other modules included in the ENTROPY platform. These requests may be of two different types:

- A request to gather the documents from a set of specific users in one or more social network sites within a specific time interval. Such users can actually be the set or a subset of the participants in the ENTROPY pilots. In this case, this type of request is intended to enrich the feedback collected by the mobile apps and serious games.
- A request to gather the documents in one or more social networks published in a

particular spatial region within a specified time interval. This request profits from the geo-tagging performed by most of the social-network sites to their documents. In this case, this type of request can help to discover new contextual data concerning a pilot scenario that can be helpful. For instance, collecting the tweets around spatial region can help to discover certain ad-hoc social events that might have an impact on the occupancy of a target building.

All the requests sent by ENTROPY modules will be handled by the crawler module. Depending on the request parameters, it will directly access to the public APIs of the set of target sites in order to collect the data. In addition to that, this component also keeps historic data of social-media documents in order to handle requests covering a large time interval.

3.4 Entropy MCS Approach of Open Data

As already mentioned, in ENTROPY, as crowdsensing we also consider open data from repositories made available by public organizations and containing mainly data collected in smart cities environments. The main objective for the usage of such data regards the realisation of comparisons among energy efficiency campaigns realised in similar or close to similar setups as well as the realisation of set of analysis taking as input energy efficiency as well as other environmental, societal or business oriented parameters (e.g. examining energy efficiency achieved with regards to temperature, or income level).

Set of indicative open data repositories:

- <http://eemeasure.smartspaces.eu/>: energy savings data and project information.
- <http://www.eia.gov/consumption/data.php>: including Residential Energy Consumption Survey data.
- <https://catalog.data.gov/dataset?groups=energy9485>: USA energy data catalog
- <http://www.engagedata.eu/>: The main goal of ENGAGE project is the development and use of a data infrastructure, incorporating distributed and diverse public sector information (PSI) resources, capable of supporting scientific collaboration and research, particularly for the Social Science and Humanities (SSH) scientific communities, while also empowering the deployment of open governmental data towards citizens.
- <http://ec.europa.eu/eurostat/data/database>: energy data by Eurostat
- <http://www.eia.gov/opendata/>: The U.S. Energy Information Administration is committed to enhancing the value of its free and open data by making it available through an Application Programming Interface (API) and open data tools to better serve our customers.

It should be noted that in ENTROPY we exploit existing open-source implementations for supporting the representation of data based on specific models (including ENTROPY semantic models) as well as the creation of linked data based on the combination of data provided by diverse data sources. Namely, the open-source LinDA workbench -released by the LinDA FP7 project [LINDA2016]- is envisaged to be used for creating the required linked data -where

applicable- and feed the output to the ENTROPY platform for further analysis. In this way, exploitation of the vast amount of open data made available worldwide can be achieved.

In more detail, the following workflow may be followed by using the LinDA workbench [LINDA2016][FOTOPOULOU2016] along with data collected within ENTROPY:

Step 1 – Explore datasets/Turn data into RDF: using the LinDA toolset, users can publish their data as linked data in a few, simple steps. In cases where the data are not available in RDF format or cannot be fetched through a SPARQL Protocol and RDF Query Language (SPARQL) endpoint, the users can simply connect to their data sources endpoints, select the data they want and make their mappings to popular and standardized vocabularies. LinDA assists even more by providing automatic suggestions to the mapping process. Based on the defined mappings, transformation from various formats (e.g. comma-separated values, relational database) to RDF is realized. ENTROPY collected data is already provided in a JSON-LD format, thus the support of this step is going to be based on one of the following processes: (i) extract data from ENTROPY MongoDB and inclusion them in the LinDA workbench based on the development of a customized script or (ii) submit queries in ENTROPY MongoDB, upload results in LinDA repository, map the data based on the ENTROPY semantic models and store the mapped data in the LinDA repository.

Step 2 - Query/Link your data: with the LinDA toolset, users can perform simple or complex queries through an intuitive graphical environment that eliminates the need for SPARQL syntax. In addition to the submission of queries, interlinking of instances is supported, where the designer lets the end user ignore its instance's data source and handle instances as if they were defined in the same data source. The possible types of interlinking vary according to the interlinking element that is used. More specifically, classes and object/datatype properties can be combined in a versatile way, during the interlinking procedure.

Step 3 - Analysis with ENTROPY data: the LinDA toolset can help end users gain insights from the data that they process through the support of a set of visualization and analytics services. LinDA supports visualizations over different categories of data, e.g. statistical, geographical, temporal, arbitrary data, as well as a largely automatic visualization workflow for matching and binding data to visualizations.

4. CONCLUSIONS

This document overviews the mobile crowd sensing mechanisms designed and developed in the ENTROPY project. The set of mechanisms include mechanisms for collection of data from the ENTROPY personalised applications and serious games, mechanisms for collection of data from sensor devices owned by end users (e.g. embedded sensors in the mobile devices), mechanisms for collection of data from social media and mechanisms for interlinking of available data with existing open data and realisation of analysis over them.

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