A mobile crowdsourcing platform for urban infrastructure maintenance

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Abstract— **Geospatial mobile applications interact with local and remote hardware to connect various data sources. These applications are currently evolving to include crowdsourcing functionalities, for citizen participation. In this paper we propose the identification, collection and information exchange of smart objects their geographic information, facilitating connectivity and communication between citizens and local organizations, and building interoperable services with data from sensors, smart physical objects and social media. We propose to identify spatial patterns, report object locations to identify problems and improve maintenance strategies of a city. As a validation of this approach, we develop a mobile mapping and data hub platform to visualize, monitor, and assist urban maintenance planning that enables better interaction between citizens of Smart Cities.**

Keywords- NFC; crowdsourcing; social media; geographical characterization; geo-information

I. INTRODUCTION

The evolution of ICTs and wireless personal devices has led to facilitate the collection of different type of data, increasing the user-generated content and availability of information on Internet. As a result, there are several changes on the way people communicate and connect; hence an increased involvement of citizens in public and local affairs is gaining popularity. The term "crowdsourcing" introduced by Howe [1] is a modern model for problem solving, and in different topics related to geo-information management, is an efficient tool for data acquisition and analysis. Crowdsourcing models are based on the use of perceptual and cognitive abilities of a large group of individuals to obtain faster and efficient solutions [2].

Citizens are primarily interested in a suitable, friendly and safe place to live and develop their life project. For this reason crowdsourcing models offers to people the opportunity to manage their immediate and local environment. In addition, the increasing trend on cities to provide better infrastructure and more efficient services has contributed to the popularity and use of the concept of Smart City. Their definitions vary from the discreet use of new technology applications based on the Internet of Things (IoT) and Big Data, to a more holistic conception of urban intelligence, integrating user-centered, open-innovation ecosystems and also user-generated services [3].

In a more social view of a Smart City, systems gain intelligence from both digital and human elements, and people are actively engaged in systems as participants. Consequently, they can contribute with their knowledge and expertise to systems [2], integrating "digitally" people, things and their environment, as a convergence of the Smart City and crowdsourcing paradigms.

Crowdsourcing in urban contexts is a viable model for several reasons. Cities are dense concentrations of people, which have interest in participating in systems that impact their daily life. Also, people are often identified with their urban context, families, friend or communities. This pre-existing social structure is a valuable asset that geocentric crowdsourcing exploits [2].

Information exchange and cooperation are key ideas in the Smart City paradigm and crowd-centers models. Such ideas are shared with open source software, considered as a valuable source of technologies and applications that can be used in the implementation of smart platforms. Also, some technologies provide transparent access to information and services through integration into the Internet. Specifically, smartphones with Near Field Communication (NFC) capabilities make use of various contextual applications like marketing, payment, identification, access control, etc., enabling interaction between devices, things and persons. The low range of NFC transactions allows the possibility of using proximity as context and triggering an appropriate action almost instantaneously [4].

This paper proposes a novel application platform that integrates the use of NFC geo-located tags on urban static infrastructure to allow citizens to make public participatory reports to identify problems and improve maintenance strategies of a city. Furthermore, this mobile mapping and data hub platform integrates crowdsourcing functionalities to generate geo-located urban maintenance related events and reports, display urban smart objects inventory and publish social media data in order to increase the participation of citizens in the urban infrastructure maintenance and conservation.

The remainder of the paper is organized as follows. Section II describes some related work regarding crowdsourcing research and implementations; Section III presents the proposed mobile data hub platform design and an application scenario. Section IV provides a brief description of the architecture, including the components,

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system prototyping and data flow. Finally, conclusions are presented and future work discussed in Section V.

II. Related work

Many research proposals and software technologies are constantly innovating ways to manage geographic data provided voluntarily by individuals in different contexts. Some works consider that the future of decision-making and e-governance will profit from the collaboration between government and people, authoritative data and crowdsourced data that includes both, data creation and editing. The proliferation of Web based technologies is causing the creation of new applications and ways of using geographic information in society, providing tools that facilitate the study of physical elements, people and connectivity [5].

For example, citizens and organizations have used platforms like *Ushahidi*[1] or *InfoAmazonia*[2] to collect and visualize real-time geo-referenced data after special events and critical situations, *Shareabout*[3] to gather crowdsourced public input, collecting locations from citizens and especially used for transportation planning, participatory budgeting and resiliency mapping. Specifically, *Shareabouts* was used by The City of Cincinnati to collect citizen-suggested locations for a bike share feasibility study. The obtained data played a significant role in determining the recommended station locations [6]. In 2007 *FixMyStreet*[4] was created in order to make it easy for citizens in the UK to report problems in their area. Since then, over 200,000 problems have been reported to UK councils using this platform.

Other research initiatives focus on the support of the Web 2.0 and crowdsourcing models in spatial planning. A social network analysis was implemented by the National Weather Service as a case study. During and in the immediate aftermath of the tornado of May 20, in Oklahoma, Twitter was used for crowdsourcing hazardous weather reports from citizens. The analyzed results evidenced the value of the use of social media in close collaboration between the government and volunteer citizens acting as tornado watchers. This media enabled multi-directional interactive conversations and crowdsourcing [7]. The geographic references obtained were used in a master plan debate for a university campus to simulate this debate in the map-based forum. As a result, the research demonstrated how the online map provides an overview of the status and spatial hotspots of the debate, and their use to understand the spatial thinking processes of the participants [8].

[1] Ushahidi web site, http://ushahidi.com/products/ushahidi-platform/
[2] InfoAmazonia web site, http://infoamazonia.org/
[3] Shareabouts web site, http://openplans.org/work/shareabouts/
[4] FixMyStreet web site, http://www.mysociety.org/projects/fixmystreet/

III. Mobile data hub platform design

A. Motivation

To explain the motivation for this paper, we present the following scenario. An increasing number of citizens connected to Internet via wireless devices such as Smartphones, are interested to discuss, identify and report local problems. The access of mobile sensors facilitates the data collection and the communication between systems. In order to impact the social dynamics in more connected cities we propose the use of open-source platforms and technologies for reporting common street problems, adding the integration of functionalities to allow the exchange of information between citizens and urban infrastructure smart objects, monitoring their condition using a crowdsourcing approach.

B. Platform design

The City as a Platform model [9] aims to empower the citizen by facilitating the development of applications and services. For better integration of applications it is important to allow interaction with hardware (mobile devices and their integrated sensors), enabling "intelligent data" spots in the city, and to be oriented towards empowerment of citizens that usually includes elements as crowdsourcing. In addition, Smart City applications should have the following elements: sensible, connectable, accessible, ubiquitous, sociable, sharable, visible and augmented [10].

The proposed platform provides certain of the principal elements mentioned before. We focus in facilitating the interaction between citizens and hardware. The solution is accessible on the Web and is optimized for different types of mobile devices. A key objective of the solution is to link digital and physical urban spaces, increasing community engagement in a collaborative improvement of the city.

The three core functionalities of the platform can be described as follows:

1) Identify, collect and exchange data, using NFC enabled smartphones and NFC tags to promote public participatory inventory and monitoring of urban static furniture via web reports.

2) Provide interactive mapping and visualization of three classes of citizen reports: a) *Urban SmartObjects* layer shows the location of static urban smart objects that are inventoried with NFC tags and their reports with condition status and need of repairs. b) *GeoReports* layer includes problem reports from all non-inventoried and non-static urban infrastructure, like dangerous structure, road or pavement defect or obstruction likes potholes, trees, etc. c) *Community events* layer provides geo-located information from the citizens that summon the public participation to work towards improvement of the city. Some event categories are meetings, workshops, mapping parties or other kind of organized social intervention.

3) Integrate *hashtagged* data and display the citizen

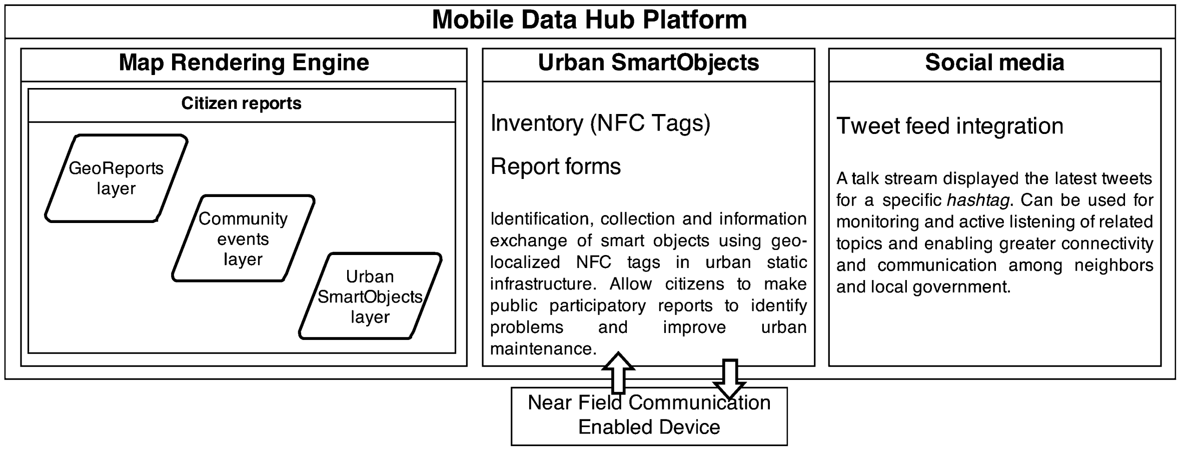

Figure 1. Platform modules

conversation about topics related to urban maintenance and surveillance. This enables greater connectivity and communication among neighbors and local government.

Each functionality described before is implement in the system modules. Figure 1 shows the modules that compose the Mobile Data Hub platform. The three components presented are: *Urban SmartObjects* inventory related with functionality 1, *Map Rendering Engine* with the citizen's reports layers where function 2 is implemented, and *Social media* integration associated with the last functionally.

IV. Mobile Data Hub Platform Implementation

In order to implement this proposal, we decide to build a custom instance of the collaborative, mobile mapping and social hub platform called "Tidepools". The mobile version of Tidepools is an open-source customizable local mapping platform built using primarily JavaScript frameworks, LeafletJS for mobile-friendly interactive maps and MongoDB as noSQL database. One of its key functionalities is to gather and share hyperlocal information, sensors and data feeds, and to enable the provision of custom APIs that makes easy to grow the "Data Ecosystem" [11].

To manage the *Urban SmartObjects* inventory and to integrate with the Tidepools' main functions, we provide some HTML/JavaScript forms to access data from CartoDB cloud-based geo-spatial database using their SQL API. The final result is the integration of all modules of the proposed platform into the mapping and visualization main component.

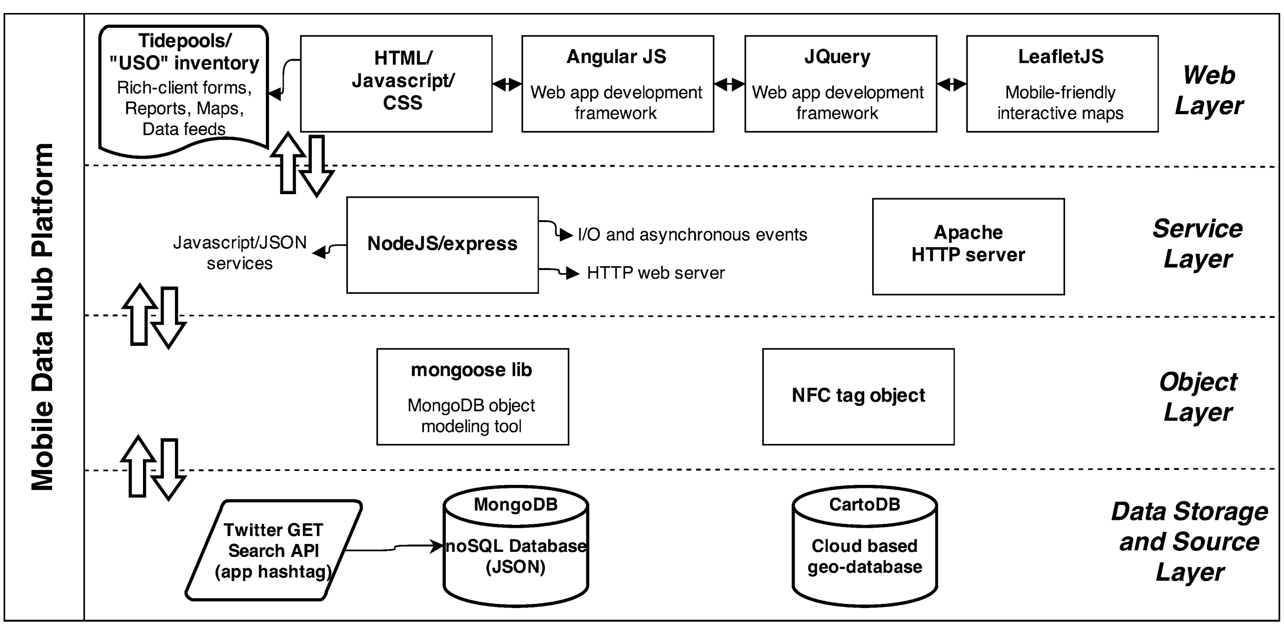

Figure 2. Platform architecture

A. Architecture

The architecture of the Mobile Data Hub platform presented in this work is described in Figure 2.

The *Web layer* contains all the components needed to interact with end-users, including dynamic maps and rich-client forms to make reports. It is coded primarily in JavaScript/JQuery, using especially AngularJS, a framework optimized for single-page mobile web apps, with LeafletJS integrated for interactive mapping support.

The *Service layer* organizes the logic, encapsulates the core functionalities of the application, and also exposes data to the web layer as the primary consumer of the functionalities it provides. In this layer NodeJS and the Express framework are used to handle I/O asynchronous events, to expose data in JavaScript/JSON formats, and to provide a server for the Tidepools components. NodeJS is also used to collect the live API stream of tweets through the execution of a script.

The *Object layer* describes the elements used to link between the application logic and items to interact with data. After the NodeJS framework gets the data streams, Mongoose is used to access and re-map the data into the Tidepools *GeoReports*, Events and social data schema. Data streams are stored in MongoDB.

The *Data Storage* layer includes the necessary databases to store *Urban SmartObjects* inventory and reports. CartoDB is used for that task.

B. Data flow

With the purpose to identify how data flows through the platform, the process diagram shown in Figure 3 was designed. It presents the logic of the entire system, identifying where the data comes from and flows, as well as where it is stored. The platform has two integrated and main functions where the manipulation and transformation of data take place.

The first function is *Urban SmartObjects* status report. To use this function a citizen starts a NFC tag reading process of an *Urban SmartObject*, interacting with a NFC enabled smartphone. With a HTTP Get method request the application queries CartoDB database to select the attributes of a specific object filtering the inventory database by the NFC Id variable obtained from the key-value pairs information of the URL written in the NFC tag.

After the user gets and validates the data of the selected urban infrastructure, the form permits to start a report to determine the condition and problems of an object. After the form is submitted, the app inserts a new row in the *Urban SmartObjects* report database in CartoDB with their latest status update and is presented as a geographic layer in Tidepools map. Figure 4 presents the forms layout for citizen reports of urban static infrastructure.

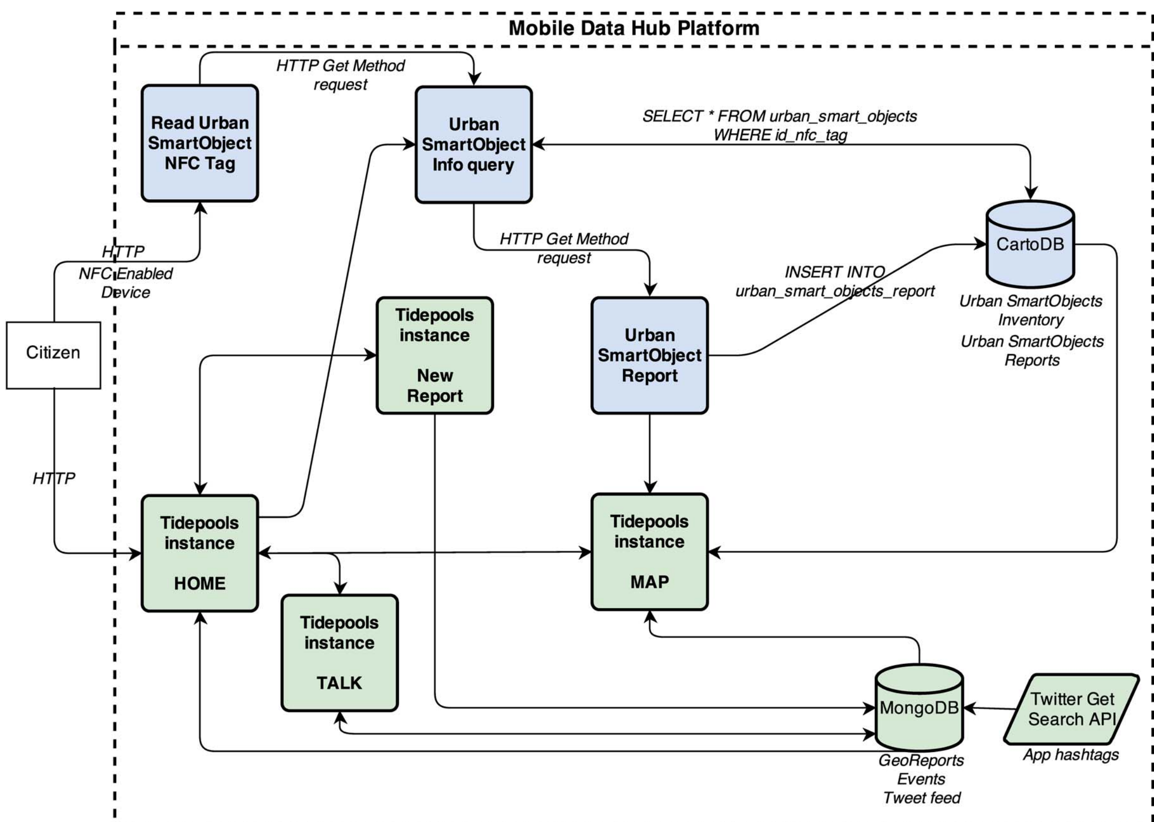

Figure 3. Mobile Data Hub Platform process diagram

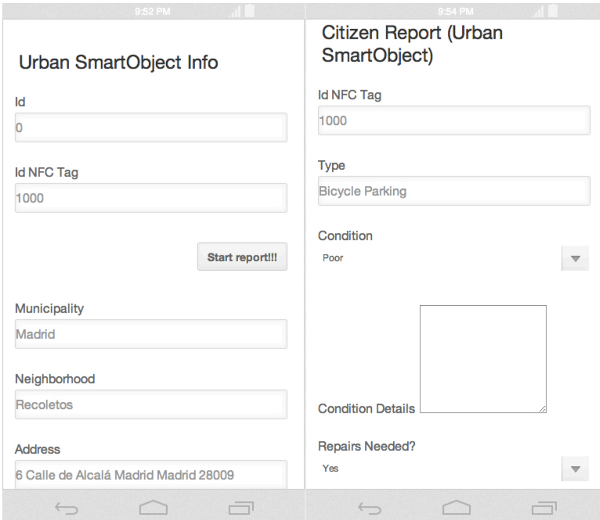

Figure 4. Forms used to manage an *Urban SmartObject*

The second function is Tidepools instance user interaction. To use this function, the citizen enters the Home section (Figure 5) of the Tidepools instance via web browser. This section presents the last tweet that comes into the platform, but also a scrollable list with the description and particular data of every *GeoReport* or Event created within the platform. This citizen-generated information and the tweet feed pulled by the Twitter Get Search API are stored in MongoDB. Additionally, this

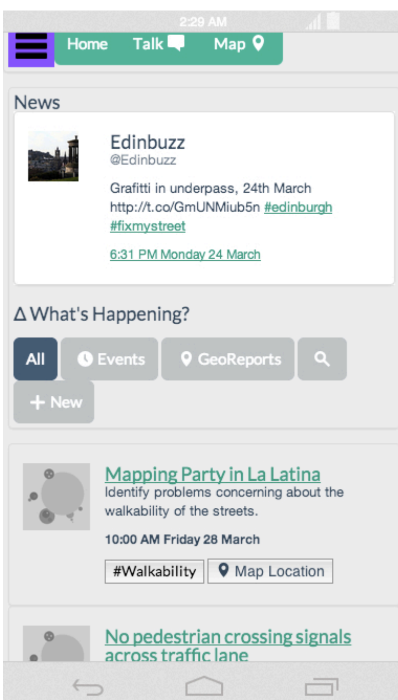

Figure 5. Home section

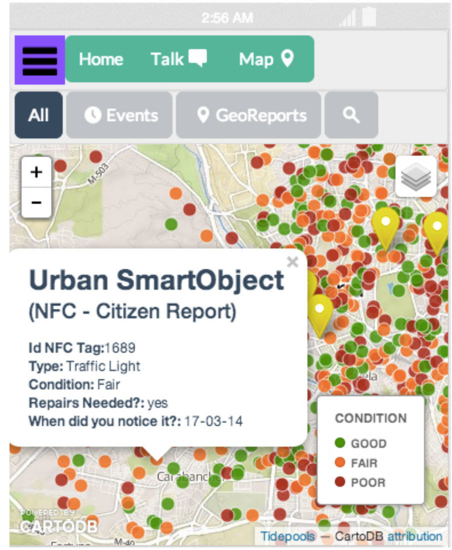

Figure 6. Map section

section allows the citizen to add new *GeoReports* and Events, linked to the Talk and Map sections.

The main goal of the Talk section is to integrate *hashtagged* data into the platform, and to display the citizen conversation about topics related to urban maintenance and surveillance allowing a better collaboration among citizens.

The Map section (Figure 6) represents one of the most important processes in the platform, as it represents all data from the three types of citizen spatial reports. The Map section is connected to CartoDB and MongoDB to visualize the geo-data and presents the attributes collected by citizens in the platform forms. In all sections there is a shortcut to the *Urban SmartObjects* status report functionality, using the slide-out enabled menu.

V. Conclusions and Future Work

In this paper, we proposed a novel mobile crowdsourcing data hub platform to manage public participatory reports for urban monitoring and maintenance. A crowdsourcing constitutes a useful means for creating data about the physical world, in particular through the use of smartphones and their rich set of on-board sensors (GPS, NFC) and capabilities (Internet, audio, video, etc.). This model also permits to acquire and share local knowledge from the people that improves and facilitates their collaboration in a citizen urban observatory platform.

We have implemented the platform demonstrating the usefulness of readable NFC tags to access a web mobile platform to process data from urban static objects and report problems to local government. Also, we show how to integrate geo-located general reports, events and social media feeds, enabling greater connectivity and communication among citizens and authorities.

Looking to the future, we shall work on design techniques to better process and filter the data of the platform to extract more useful actionable information as input layers to GIS analysis. To illustrate this point, the extracted data will enable report tracking on the map and over time, by using database historic reports, will contribute to facilitate the logistic planning in civil engineering departments, obtaining statistics per geographic area units, graphs visualization and tweet classification clustering for data mining.

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