Towards Ambient Assisted Cities and Citizens

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***Abstract*—Research on Smart Cities brings about ICT innovations towards aiding users in their daily activities, anticipating to their needs or suggesting service consumption towards a better vital experience. The city is a challenging environment for anybody elderly or with disabilities. Addressing these challenges so that elderly or disabled people encounter inclusive, friendlier, cities which are not frightening but supporting is the motivation of this work. Concretely, it lays out the ICT basis over which an ecosystem of user-centric urban apps aiding citizens in their daily activities may be assembled.**

Keywords: *assistive, urban, apps, Smart Cities, Linked Data*

I. INTRODUCTION

The world is experiencing a dramatic shift in demographics. Urban populations will grow by an estimated 2.3 billion over the next 40 years, and as much as 70% of the world's population will live in cities by 2050. Besides, by 2050, the number of people over the age of 60 is expected to triple, and will outnumber children under 15 for the first time in human history, as shown in Figure 1.

A *Smart City* can be defined as a means of making available all the services and applications enabled by ICT to citizens, companies and authorities that are part of a city's system. It aims to increase all citizens' quality of life and to improve the efficiency and quality of the services provided by governing entities and businesses.

According to the World Health Organization [1], people with disabilities make up about 15% (about 1 billion people) of the world's population. Therefore, it is clearly necessary to consider the creation of *Ambient Assisted Cities*, i.e. cities aware of the special needs of all their citizens, particularly those with disabilities or about to lose their autonomy. The target collectives are: a) *Elderly people*: in their three categories, namely the "Young Old" 65-74, the "Old" 74-84 and the "Oldest-Old" 85+; and b) *people with disabilities* either physical, sensorial (visual, hearing) or intellectual.

Many cities have been investing on becoming more accessible, mainly focusing on mobility and on granting access to services to any person. As a consequence, diverse public spaces in cities have been transformed and instrumented. Some examples of these efforts are: a) pedestrian ways' barriers have been eliminated, b) traffic lights have been enriched with sound and c) sensors and actuators have been spread throughout the cities configuring sensor networks that measure and react upon the main variables that characterize any activity within a city.

However, how do we progress towards truly inclusive cities? How do we move from controlled indoor Ambient Assisted Environments [2] into more generic and ample Ambient Assisted Cities? We deem that it will not be enough with enriching our cities with infrastructure and the associated services made possible through it. From the beginning, the provided services should adapt to the citizens and their diverse needs. They should be, in fact, citizen-focused and not council-focused. This is, Smart Cities should not only enable more efficient and effective management of the city resources, saving and optimizing costs. The end goal should be to increase comfort and satisfaction from all population sectors, without neglecting elderly and disabled people.

In order to make Ambient Assisted Cities feasible, both technically and economically, we propose to leverage from the rapidly expanding urban-related open data initiatives, the extensive sensor networks already deployed in cities and the widely deployed smartphones among citizens. Taking advantage of already existing urban technology and data, without going through new costly and timely infrastructure deployments, it is possible to configure an ecosystem of citizen-centric urban apps that may assist all citizens, independently of age or their abilities, in their daily activities. The rest of this paper describes the technological approach that may be followed to make the Ambient Assisted Cities concept a reality.

II. RELATED WORK

There is a growing interest in Smart Cities' research. Big academic and industrial such as the MIT with the Smart Cities Media Lab[1] or IBM with its Smarter City [4] are showing increasing interest in this domain. Among other topics, those initiatives are working on low cost wireless sensor solutions to enable urban agriculture, provide public health or ensure better connection between people and the environment.

Other examples of major corporations' efforts on Smart City projects are: SIEMENS mobility solution [5], CISCO Smart+Connected Communities [6] or Philips Livable City

[1] http://cities.media.mit.edu/

[7]. Those corporations generally offer "Smart-city-in-a-box" platforms where the main management areas of cities are tackled: intelligent transport systems, water and waste management, pollution or even health. They integrate proprietary sensing solutions and integrate them with the already existing IT infrastructure in the city, offering central coordination and decision making dashboards for the cities. However, a main limitation of their approach is that they offer closed, proprietary, single-branded solutions which do not give place to Open Innovation [8]. They do not foster citizen participation or openness of city data, which may enable the citizens themselves or third parties to generate, continuously, novel solutions that address the needs of the actual citizens, including disabled and elderly people. In a nutshell, they are focused on increasing the overall efficiency of cities but not necessarily the comfort and satisfaction of their citizens, by hearing their actual demands.

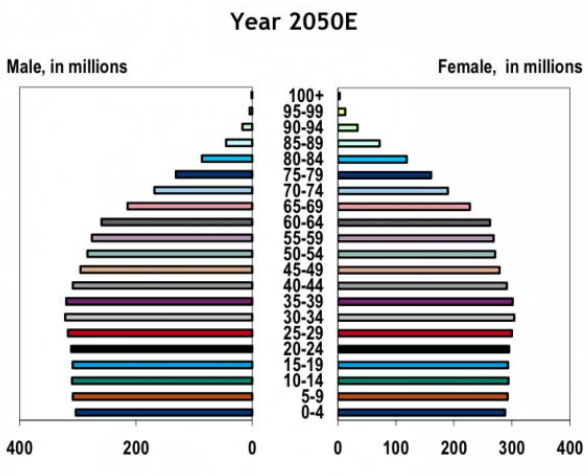

Figure 1. World population in 2050 [2].

A confronting approach to the proprietary solutions of big corporations is represented by "Apps for Smart Cities" [9] or New York City Apps [10]. Such initiatives foster urban creativity through citizen-centric apps towards enhancing the quality of citizens and visitors. Grounded on Councils' citywide sensor networks' and Open Data, together with citizen participation, they provide more user-sensitive solutions. They give place to *Smart Cities apps* a.k.a. *urban apps*, i.e. mobile applications that integrate Internet of Things (IoT) enabled spaces with Open Data and Citizen participation in order to offer value-added services to the city.

In the area of Smart City accessibility, there have been several attempts to incrementally provide services within Smart Cities suitable for all publics, including disabled and elderly people. A good example is AccessMyNYC [10]. It is an app designed to help define requirements for more inclusive Smarter Cities. It brings together geo-location and mapping technologies, transport data, and publicly available accessibility information to help New York residents and visitors. Among other things, it allows citizens and visitors to find information about accessible public and private transportation and plan a public transit or walking route; or to identify accessibility information about points of interest citywide. Similar projects such as VIABLE [12] and LibreDeBarreras [13] have also sought social participation to update and publish in real time information about the accessibility status of the public ways and buildings.

Other initiatives have also explored how cities can promote healthier lifestyles and Active Aging [14] by using their urban wireless infrastructures and open data repositories to implement mechanisms that encourage residents to play sports and exercise or, that assist older people to remain healthy and engaged in their community. RunWithUs [15] is a pilot deployed in Oulu to motivate city residents to exercise. It defines as social network of residents that can challenge each other.

This work aligns with the Smart Cities app vision by proposing a platform for Ambient Assisted Cities that will enable the creation of a growing ecosystem of user-centric apps that help citizens, taking into account their disabilities, in their daily activities.

III. SOME EFFORTS TOWARDS MORE ACCESIBLE CITIES

An Ambient Assisted City enabling platform for more inclusive and accessible Smart Cities should be based, in our view, on the following core concepts:

1. *Seamless, low-cost and feasible city instrumentation*
2. *Accessible user interfaces for applications*
3. *User participation and contribution* and
4. *Exploitation of currently existing ICT infrastructure within cities*, e.g. council's open data and citywide sensor networks

This section describes our earlier contributions addressing these core concepts independently. Concretely, it describes our earlier contributions on: a) low-cost widely deployable sensing infrastructure in public spaces, b) app interface adaptation bearing in mind user and device capabilities and c) how to seek active user participation to address the actual needs of end-users.

A. *From BlindShopping to Assisted City Exploration*

The BlindShopping project [16] enables accessible shopping for visually impaired people through mobile technologies. It targets an important collective who experiences significant difficulties in their daily life tasks. A key assumption of the project was to assume that the majority of blind people possess a smartphone with increasing computing, communication and sensing capabilities which can act as sensorial complement.

BlindShopping aims to provide a platform for blind people to shop autonomously in a supermarket. It contributes with: a) a *navigation system* and b) a *product browsing mechanism*.

The BlindShopping's navigation system guides blind people inside the supermarket. Location is found by combining RFID tags distributed throughout the corridors and a RFID reader attached to the white cane (see left hand side of Figure 2). The end-user issues voice commands and the system guides her to the right location through voice feedback.

The product recognition system retrieves information about pointed products to the user (see right hand side of Figure 2). Based on embossed QR codes attached to the product shelves' price and description badges, these are recognized by the smartphone's camera and the information about the products retrieved from the back-end. Verbal descriptions are generated so that the blind person can understand what is being described.

This solution is easily extendable to public spaces in order to give place to a smarter more inclusive city, both indoors and outdoors. For instance, tactile paving of some core parts in a city could be enriched with RFID tags that could then be read by RFID reader enriched white canes' to guide blind people through the city and pinpoint to them information of interest in their current location. Already existing commercial solutions such as iPavement[2] could be applied. These paving stones sport Bluetooth, Wi-Fi, their own operating system, apps, and sensors – all with the goal of connecting with locals and passersby to push information ranging from local weather conditions and emergency alerts to maps and coupons for nearby businesses.

In summary, with the low-cost widely deployable sensing infrastructure set forward by BlindShopping, it is possible to easily enable accessible services in a city. Following a similar approach, Points of Interest (POI), e.g. statues, remarkable buildings, and so on within a city, could be annotated with embossed QR codes or RFID tags readable through NFC-enabled smartphones. This is, apps and services for more accessible tourism could be enabled.

Figure 2. BlindShopping navigation (left) and product browsing (right).

B. *Imhotep: user-concious interface adaptation*

The Imhotep project [17] offers user-conscious adaptable mobile interfaces. It targets the collectives of elderly and disabled people who usually have limited access to technologies and mobile apps. However, this user base is growing with the increase of average age in Europe, USA or Japan. Therefore, there is a clear need for adaptive interfaces sensible to end-users capabilities.

Developers traditionally tend to ignore or neglect this user base. The individual user groups (each disability has different requirements) may not be big enough to justify the additional development costs. Consequently, developing accessible applications can be difficult and error-prone.

Imhotep provides tools that ease the development of adaptive, user-centric accessible applications. Its design objectives are to: a) make the framework platform independent; b) reduce the adoption costs; and c) help AAL programmers without expertise in developing accessible applications.

The solution is composed of three main elements: a) the pre-processor directives, b) the adaptation server aware of user and device capabilities and c) the fuzzy knowledge-eliciting reasoner (integrated in the adaptation server). *Conditional* programming directives can be used to avoid the compilation of fragments of code if certain conditions are matched. These conditions can include calls to functions provided by the framework. The fuzzy knowledge eliciting reasoner allows inferring new user and device capabilities from those specified in the user profiles. Moreover, it enables the AAL developers to abstract from the crisp values (*the user has less than 3 dioptres*) in favour of more natural concepts (the *user can see without a significant problem*). For more details on the technical and scientific approach followed by Imhotep refer to [17].

The Assisted City app, see Figure 3, is an Imhotep-powered app to search nearby interesting locations (bars, restaurants, hotels, etc.), adapted to the user requirements and capabilities. Such app offers different facets depending of the type of user:

- *Adapted to blind users*. Uses the Android TextToSpeech API to communicate and a graphic interface with different colors and font sizes to ease the reading.
- *Adapted to regular users*. Users are driven to the selected point through Augmented Reality. As can be seen in Figure 3, the distance to the point and a marker indicating its position are shown by overlaying textual information over the device camera's image.

App interface adaptation, bearing in mind user and device capabilities, is mandatory to enable the Ambient Assisted City concept, where an ecosystem of diverse user-conscious apps are provided to ease all citizens' daily activities in an accessible manner. Therefore, it is very important to translate Imhotep adaptation user interface contributions to the current norm for mobile apps, i.e. HTML5. Generating accessible HTML5-based mobile apps is possible providing the following is considered: a) use clean HTML, standard tags, b) manage focus by allowing tab usage, c) add key handlers so that the use of mouse is not required and finally d) add ARIA attributes so that they can be interpreted by browser's screen readers, e.g. ChromeVox.

HTML5 WAI-ARIA [18] is a specification defining support for accessible web apps. It defines a bunch of mark-up extensions (mostly as attributes on HTML5 elements), which can be used by the web app developer to provide additional information about the semantic of the various elements to assistive technologies like screen readers. Of course, for ARIA to work, the HTTP user agent that interprets the markup needs to support ARIA, but the specification is created in such a way, as to allow down-level user agents to ignore the ARIA-specific markup safely without affecting the web app functionality.

[2] http://ants-webs.inf.um.es/conferences/pitsac/

C. *MUGGES: user prosuming of data and services*

The Mobile User Generated Geo Services (MUGGES) project [19] enables end-users to develop their own services, provide and consume them. Users keep at each time full control about their contents. A key feature in MUGGES is its location management system (LMS) which combines seamlessly, different location technologies in order to offer a semantic location abstraction that helps matching services to user needs.

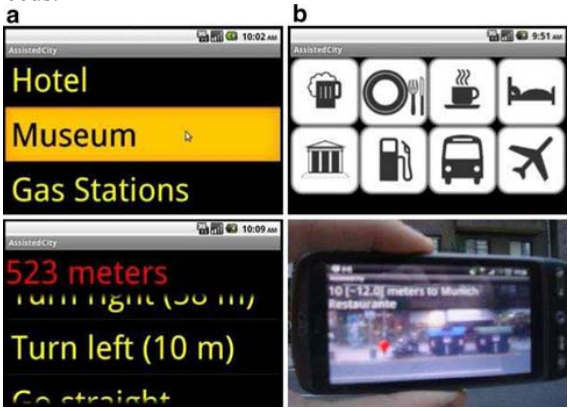

Figure 3. Ambient Assisted City Application

The MUGGES platform, see Figure 4, is modeled as a triangle with no central service content provider but a central facilitator to enable direct peer-to-peer (P2P) connections between producers and consumers. The service provider creates a given service (mugglet), and publishes it through the service infrastructure. A published mugglet can be searched for and found by other MUGGES users. Since MUGGES aims to offer serendipitous instant access to contents offered from location- and topic-relevant mugglets, connection details for relevant mugglets are recovered from the server-side, enabling direct communication from the client-side.

Once the connection details of a mugglet are received, the consumer device can remotely consume and render the mark-up corresponding to the mugglet front-end. Communication is then handled directly through sockets (TCP/IP) between the mugglet provider and the consumer through wireless technology.

On the infrastructure-side, a central Controller component offering a REST API, implemented through the Restlet framework, acts as gateway for the client-side to access the server infrastructure. The Warehouse component hosts a storage system based on PostgreSQL for mugglets and their related templates. It allows users to search for existing mugglets or available templates from which new mugglets can be instantiated based on keywords, template category and location. Since mobile devices may use different positioning technologies, a Location Server supports the translation between different location concepts. Such server makes use internally of the PostGIS spatial database extension to PostgreSQL, so that sophisticated spatial queries related to mugglet locations can be carried out. Finally the User Management and Accounting Servers provide user and community profile management functions and also record information required for billing or user traceability purposes.

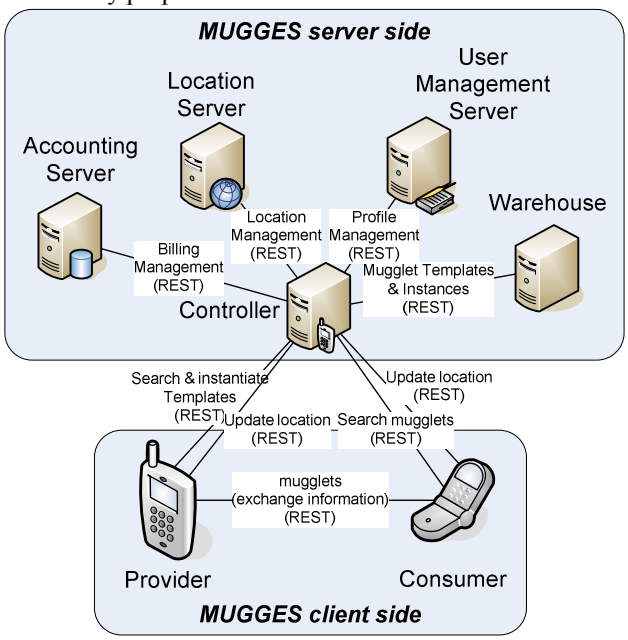

Figure 4. MUGGES platform distributed architecture.

MUGGES brings about two key innovations that should be incorporated in any Ambient Assisted City-enabling platform: a) *context-awareness*, particularly location-awareness, to dynamically match make user profile, preferences and current context (location) against available services and b) *user participation* by giving them the "voice", i.e. allowing them to define and publish new services which will be consumed by others.

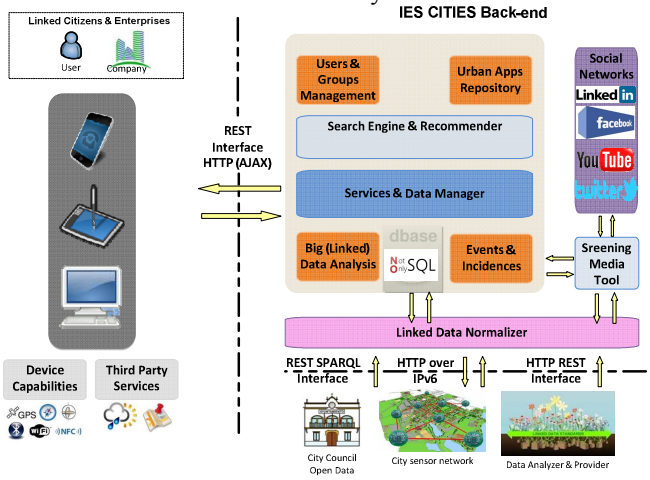

Figure 5. IES CITIES conceptual architecture.

IV. AMBIENT ASSISTED CITIES

In our view, the "appeal and inclusiveness" of a city will be capital to attract and retain citizens, companies and tourists. For that, it is paramount that cities show a user-driven and centric innovation in the form of a range of

services/apps that aid them in their daily activities and interactions with the city:

- *The citizen should be heard*, i.e. empowered. Urban apps should be created to enhance the experience and interactions of the citizen, by taking advantage of the city infrastructure.
- *The information generated by cities and citizens must be linked and processed*. However, for that we must first correlate, link and exploit such humongous data for all stakeholders' benefit. We have to start scratching the Big (Linked) Data area.

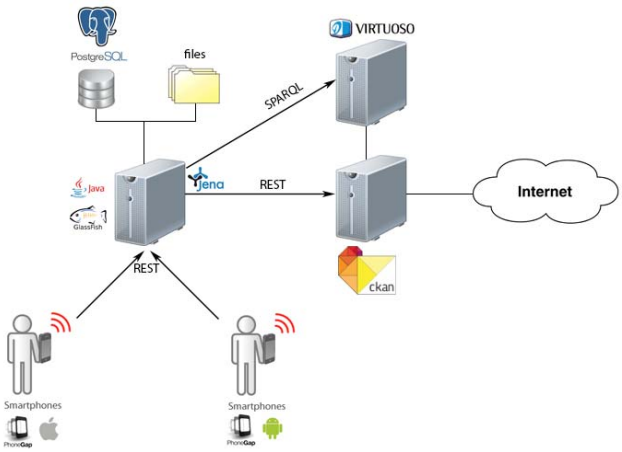

Figure 6. IES CITIES prototype architecture.

The IES CITIES project envisions the generation of user-centric and conscious (bearing in mind their possible disabilities or advance age) solutions that exploit the user context and urban data in different domains, namely social networks, council's open data and data extracted from the city's sensor network, and thus improve the use of existing urban infrastructure and resources. Thus, a sustainable and open ecosystem vs. "smart city in a box" will be configured. Its ultimate goal is to create a multi-device dataset and application marketplace based on standard and accessible web technologies, that exploits the data shared by councils and their citizens, and provides to citizens, tourists and workers an enhanced experience in a municipality. The objectives set by the project are as follow:

- Transform and release municipalities' open data into Open Linked Data
- Generate structured council data from non-structured data coming from social networks or directly facilitated by users through urban apps.
- Integrate, normalize, link and publish data for its massive analysis and exploitation by councils, enterprises and citizens.
- Generate a scalable Cloud-based and NoSQL-based infrastructure that supports the urban apps marketplace.
- Create a set of fully accessible urban apps over the normalized data of a council, its citizens and companies
- Disseminate and transfer the service and data marketplace platform to companies and administrations

Figure 5 shows the conceptual architecture of IES CITIES where end-users (citizens) consume apps built around data extracted, linked and managed by the IES CITIES back-end. A core element in such back-end is the *Linked Data normalizer*. This component curates the data provided by citizens either through social data channels or directly from their smartphone applications. It translates the non-structured information gathered from social networks or the semi-structured data gathered from apps and the city's sensor network into structured data, which is linked with the open data sets managed by councils. This component, currently under development, integrates the results obtained from two projects in the area of social data mining, namely SABESS [3], and holistic infrastructure for Linked Data extraction, mapping, linking, quality assurance and exploitation, namely ADAPTA[4].

Figure 6 illustrates the technologies and protocols used to produce the first working IES CITIES prototype. A GlassFish application server, accessible via REST, hosts the server-side of urban apps who exploit citywide Linked Data. In our implementation CKAN is used to manage the metadata of the adapted urban datasets whilst OpenLink Virtuoso is used to store them. The PhoneGap framework has been used to create the IES CITIES player, a mobile context-aware app that allows recommending, searching, browsing, selecting and executing nearby relevant, according to user context and profile, accessible services, as shown in Figure 7.

IES CITIES is devised to transform cities without requiring massive investments. It will take advantage of already existing IoT and Open Data infrastructure. Furthermore, it will offer a set of open APIs so that a "city can be programmable", i.e. new apps that exploit the information generated by the city may be assembled either by the council itself, the citizens themselves or any third company who wants to offer a new pay service to citizens. Furthermore, it will provide an accessible application player and a set of guidelines to produce accessible HTML5 WAI-ARIA based urban apps.

A main concern is to enable an ecosystem of user-aware assistive applications through open innovation. The first application developed (see Figure 7), namely 311, allows a citizen to report about faults and problems detected in streets, including accessibility barriers. Other assistive apps envisaged are to provide assistive support for public transport usage or aiding navigation of POIs within a city.

V. CONCLUSION

This work has shown several proof-of-concepts illustrating how Smart Cities can be turned into more attractive and inclusive spaces for their citizens and visitors. Three earlier research efforts on accessibility infrastructure and end-user participation have been described, namely, a) BlindShopping – enhancing common public spaces

[3] http://www.treelogic.com/web/guest/sectores/seguridad/-/journal_content/56/10137/35562
[4] http://www.treelogic.com/web/guest/investigacion/tecnologias-semanticas/-/journal_content/56/10137/35701

accessibility for people with visual disabilities, b) Imhotep – adapting interfaces to user and device capabilities and c) MUGGES – giving end users the capability to go beyond consuming but also providing services from their own devices.

The ongoing IES CITIES will bring together the achievements of the mentioned earlier works that independently addressed important issues towards more assistive and inclusive cities. IES CITIES seeks a Smart City-enabling platform that will support the creation of user-centered and context-aware apps leveraging urban data in different domains (transport, environment and tourism) and already existing technology (sensor networks) to give place to more inclusive and assistive smart cities. It will exploit the sensorial, user-provided, open and social network data about a municipality to give place to an urban service and data marketplace exploitable by all city stakeholders (council, companies and most importantly, the citizens themselves). This work-in-progress will bring together, based on our earlier experience, the four key laying foundations of Ambient Assisted Cities:

- Seamless, low-cost and feasible city instrumentation;
- Accessible context-driven user interfaces for filtering, recommendation and presentation of user apps
- User active participation and contribution
- Exploitation of existing widely deployed infrastructure, e.g. council's open data and citywide sensor networks

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Figure 7. IES CITIES Player and 311 app.