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RESEARCH ARTICLE

LUCY: A SMART CITY MOBILE APPLICATION ARCHITECTURE MODEL FOR MULTIDIMENSIONAL INTERESTS SPACES AND PERSONAS USING MACHINE LEARNING MODELS

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ABSTRACT

Rapid urbanization, native mobile applications and the increase in the number of citizen created several challenges, issues or opportunities. Many initiatives have been developed under the Smart City label in a way to provide a response to challenges facing cities today. In other word, the smart city concept offers opportunities to get way with these challenges and issues, solve urban problems and provide citizens with a better living environment. Therefore, there is a strong activity on defining smart city application architecture to cope with this complexity, putting in place a significant range of different kinds of services and processes using mobile information technology and Machine Learning Models (MLM). This work propose a Smart City Application Architecture (SCAA) that focus on the citizens' expectations, in terms of smart services, than cities administrators' expectations, in terms of administration of these new smart services mobile applications using multidimensional interests spaces. To support our Smart City Model, we propose a new multi-tenants based platform prototype, called ***LUCY***.

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INTRODUCTION

According to the 1996 report of the United Nations conference on human settlements, cities are places where agglomeration economies attain their highest yields, producing cultural, economic and social benefits. However, growing urbanisation patterns create a series of problems that reduce quality of life in urban settlements, such as inequality, pollution, ageing population, insecurity and others (Fernandez-Anez, Fernández-Güell, & Giffinger, 2018). In addition, United Nations estimates that between 2015 and 2050, the world population will increase by 32% with 63% of this increase population in the cities; that's what motivates the research in the different fields of Smart City.In generic terms, Smart City is an urban environment that utilizes Information and Communication Technology (ICT) and other related technologies to enhance performance efficiency of regular city operations and quality of services (QoS) provided to urban citizens. However, the lack of consensus as to the definition of a Smart City has led to specific research on this topic. Several authors have designed conceptual and typological approaches to provide a systematic understanding of Smart City concepts and policies. Some authors focus on the essential components of Smart Cities, understanding the balance between people, technology and institutions as crucial for a city to be considered Smart; Smart City is usually seen as a tool to solve urban challenges in an increasingly urbanized and fasted world. The key idea of smart city concept is to integrate information system services of each domain, such as health, education, transportation, power grid etc., of the city to provide public services to citizens efficiently and ubiquitously. Notice that a small set of smart applications for finding information using available municipality online data does not make a city "smart". The main technical issues regarding Smart City solutions are related to data gathering, aggregation, reasoning, data analytics, access, and service delivering via Smart City application program interfaces (APIs)(Badii *et al.,* 2017).The Smart City applications focuses on applying the next-generation information technology to all walks of life, embedding sensors and equipment in hospitals, power grids, railways, bridges, tunnels, roads, buildings, water systems, dams, oil and gas pipelines as well as other objects worldwide, thereby forming the IoT. Since cities are not only hubs of human activity, but also the places where economic, environmental and societal demands are magnified, urbanization causes many important and significant economic, social and demographic transformation and process accelerations.

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Cities are commonly regional economic centers that are helpful in improving regional economic prosperity and creating more jobs. The concentration of educated people in cities helps to improve the industrial structure and promote production efficiency (Yin *et al.,* 2015). The ICTmobile usage has offered people the opportunity to reduce the scale of and/or solve some urbanization issues. During the past 10 years, city systems have become more digital, information-based and smarter, and there has been a fundamental change in the living environment of and services offer to citizens from the cities. The economy, culture, transport, entertainment and all other aspects of cities have become closely mobile applications, and the Internet has become a major part of citizens' daily lives (Yin *et al.,* 2015). Healthcare can be enhanced by improving preventive care services, diagnosis and treatment tools, healthcare records management, and patient care. Transportation systems can greatly benefit from big data to optimize routes and schedules, accommodate varying demands, and increase environmental friendliness.

Most of the Smart City Architectures are enabling Smart City Services and Applications by setting up and providing different kinds of Smart City APIs. The Smart City Application Architectures mainly differ each other from the strategy to transform data to services for the city (Badii *et al.,* 2017). In effect, several hybrid architectural solutions have been proposed in the literature, for smart Cities but not specifically about mobile applications interoperability. In particular, specific smart algorithms for data aggregation, personal assistance (chat), solutions for dynamically shaping restricted traffic zones, the production of personalized suggestions and aiming at improving sustainable mobility. These requirements necessitated a deep analysis of the existing solutions to identify and then develop a solution that allows performing reasoning and deduction on city data collected from city operators, as open data and private data, as static and real time data, as multiple domain data for producing recommendation to the citizens or other types of stakeholders. Different stakeholders have tried to understand, explain and model the smart city from their different viewpoints (Yin *et al.,* 2015).Multiple attempts have been made to formalize Smart City models, but models are needed to understand their complexity and reflect the stakeholders' role in developing Smart City technologies and their capacity to face urban challenges including eServices supported my mobile and native applications.

In this paper, we present our own model of Smart City Model, Architecture and Applications, and the interoperability between the components. Multiple layers are needed to explain Smart City Applications and different services delivered to Citizen who is the central element of the Smart City including the understanding that the citizen has his own interests and behavior. The Smart City has to enhance the capability of the mobile applications to respond to the specific interests of Citizen. To validate our model, we prototype a new multi-tenants platform, called ***LUCY*** which is mainly based on user-created content (UCC), in contrast to existing smart city applications platforms which are 90% dependent on Io T devises for data harvesting. The proposed model is based on our previous work: SMESE (Brisebois, Abran, & Nadembega, 2017a, 2017b) that allow to define the overall ecosystem, semantic harvesting proposal (Brisebois, Nadembega, & Hajj, 2019a, 2019b; Brisebois, Nadembega, N'techobo, & Djeuteu, 2017) for big data management, topic and sentiment analysis (Brisebois, Abran, Nadembega, & N'techobo, 2017d, 2017e) that help to users personas identification and textual contents semantic recommendation (Brisebois, Abran, Nadembega, & N'techobo, 2017a, 2017b, 2017c, 2017f) that is the beginning of smart agenda for our Smart City Application Architecture (SCAA). The remainder of the paper is organized as follows. Section 2presentsthe related work. Section 3describes our model and architecture for new generation of smart city that is person centric while Section 4 presents the prototype applications. Section 6 presents a summary and some suggestions for future work.

Related work: Smart City is a new paradigm in the ICT era which provides models, architectures and infrastructures, and various types of applications for citizens to access many services easily, and for governing bodies to intelligently manage and control the resources in a city. ICT is used in Smart City paradigm to sense, analyze and integrate the information in running cities. Based on the Smart City paradigm in ICT, our related work will be focused on three research fields of smart cities: Smart City Model (SCM), Smart City Architecture, Infrastructure(SCAI) and Smart City Application (SCApps) and Machine Learning Model in the context of Smart City (SCMLM).

Smart City Model (SCM): Smart City Model (SCM) (Faria, Ferreira, Jalali, Bento, & António, 2018)(Borsekova, Koróny, Vaňová, & Vitálišová, 2018)(Anand & Navío-Marco, 2018) (Ruhlandt, 2018) (Han & Hawken, 2018) (Yin *et al.,* 2015) (Pettit *et al.,* 2018) (Borsekova & Nijkamp, 2018) (Eremia, Toma, & Sanduleac, 2017) (Fernandez-Anez *et al.,* 2018) (Palomo-Navarro & Navío-Marco, 2018) (Caragliu & Del Bo, 2018) (Bibri & Krogstie, 2017) (Sikora-Fernandez, 2018) (Nilssen, 2018) (Yigitcanlar *et al.,* 2018) (Bibri & Krogstie, 2017)(Petrolo, Loscrì, & Mitton, 2017) (Ahvenniemi, Huovila, Pinto-Seppä, & Airaksinen, 2017) (Silva, Khan, & Han, 2018) should interconnect various information and communication innovative technology so as to contribute to many areas, such as Economy, Business, Environment, Agriculture, Mobility, Education, Governance, Retail, Communication, Buildings, etc., with main goal is the improvement of citizens' life quality and administration of the smart city.

Yin *et al.*(Yin *et al.,* 2015) presented an exhaustive literature survey of smart cities. They started to introduce the origin and main issues facing the smart city concept, and then presented the fundamentals of a smart city by analyzing its definition and application domains. Then, they provided a data-centric view of smart city architectures and technologies is provided. According to authors, their paper is a gateway to better understanding the concept of a smart city. Author claimed that any smart city definition should consider technical infrastructure, the application domain, system integration and data processing. In smart city application domains, they identified four essential domains: government, citizens, business and environment. Based on these four essential domains and key perspectives, authors defined a smart city as a systematic integration of technological infrastructures that relies on advanced data processing, with the goals of making city governance more efficient, citizens happier, businesses more prosperous and the environment more sustainable. In (Fernandez-Anez *et al.,* 2018), V. Fernandez-Anez *et al.* proposed a new model that aims to address urban challenges based on a multi-stakeholder partnership. Authors proposed a model that pursued two objectives: (1) to develop a conceptual model capable of displaying an overview of the stakeholders taking part in the initiative in relation to,the projects developed and the challenges they face; and (2) to use this model to synthesise the opinion of different stakeholders involved in Smart City initiatives or ongoing Smart City Models. Their methodology combined project analysis with surveys and interviews with different groups of key stakeholders (governments, private companies, universities and research centres, and civil society) through text analysis. According to author, their model meets the requirements of an integrated Smart City conceptual model, and establishes relationships between the three topics identified: the importance of governance and stakeholders, the integration of dimensions linked to the projects and initiatives implemented, and the connection of these elements with the cities' challenges.Eremia *et al.*(Eremia *et al.,* 2017) proposed a brief presentation of the evolution of the "smart city" term and the most representative characteristics of it. Authors introduced model that take into account main characteristics of smart city and its tools, available for both municipality and citizen that can transform city into a smart one. *Unfortunately, their approach is limited to description different terms of smart city*.M. Nilssen (Nilssen, 2018)examined how to categorize the different dimensions of the Smart City concept, and how these dimensions are coupled to innovation.Their typology of Smart City consisted to four dimensions of innovation: technological, organizational, collaborative and experimental. Author concluded that that there is not as much focus on technological innovations in smart city initiatives as one might expect from the theoretical conceptualizations.T. Yigitcanlar *et al.*(Yigitcanlar *et al.,* 2018) proposed a Smart City Model by identifying and linking the key drivers to desired outcomes, and intertwining them in a multidimensional framework. Authors identified three types of drivers of Smart City (community, technology and policy) which are linked to five desired outcomes (productivity, sustainability, accessibility, wellbeing, liveability and governance) where each of them represents a distinctive dimension of the Smart City Model.

Unfortunatly, authors of the Smart City Models do not put more emphasis on education, transportation, health, environment and renewable energy. We can conclude that despite the conceptual and theorical evasiveness of Smart City concept, the initiatives can be viewed as an arena for multifaceted urban innovation; in other word, technical and concrete proposals of real Smart City servicesneed to be proposed. Despite high-level popularity of Smart City concept, there is no consensus on what a Smart City is, what are the key Smart City drivers and desired outcomes are, and how the Smart City paradigm can be conceptualised.

Smart City Architecture and Infrastructure (SCAI): The Smart City Architecture and Infrastructure (SCAI) (Badii *et al.,* 2017) (Altulyan, Yao, Kanhere, Wang, & Huang, 2019)(Santana, Chaves, Gerosa, Kon, & Milojicic, 2017)(Lacinák & Ristvej, 2017)(Jalali, El-khatib, & McGregor, 2015) (Gaur, Scotney, Parr, & Mc Clean, 2015) (X. He, Wang, Huang, & Liu, 2018) (Zdraveski, Mishev, Trajanov, & Kocarev, 2017) (Nitti, Pilloni, Giusto, & Popescu, 2017) (Ta-Shma *et al.,* 2018) (Naranjo, Pooranian, Shojafar, Conti, & Buyya, 2018) (Memos, Psannis, Ishibashi, Kim, & Gupta, 2018) (Montori, Bedogni, & Bononi, 2018) (P. K. Sharma, S. Y. Moon, & J. H. Park, 2017) (Sharma & Park, 2018) (Md Tawseef Alam & Porras, 2018) should be capable to take advantage of huge amount of big data (X. He *et al.,* 2018) (Altulyan *et al.,* 2019) coming from several domains and IOT sensors (Gaur *et al.,* 2015) (Nitti *et al.,* 2017) (Ta-Shma *et al.,* 2018) (Memos *et al.,* 2018) (Montori *et al.,* 2018) (Jalali *et al.,* 2015) (Kim, Ramos, & Mohammed, 2017) for analyzing them for making predictions, detecting anomalies for early warning and for producing suggestions and recommendations to city users and operators in terms of vehicle and human mobility in the city, energy consumption, health care. C. Badii *et al.* (Badii *et al.,* 2017) proposed a smart city architecture and assessing its performance, as developed in the context of Sii-Mobility (*Supporto all'interoperabilità integrata per i servizi ai cittadini e alla pubblica amministrazione*) smart city project. Sii-Mobility project aims to provide innovative services for mobility operators and city users moving in the city and in the region, to provide solutions for sustainable mobility and transport systems. According to authors, there are several proposals for smart city architectures in the literature, but only few of them are really in place with a relevant range of different kinds of processes, such as transportation. In addition, all the Smart City architecture solutions must cope with big data volume, variety, and veracity. Sii-Mobility architecture consistes: (i) a data aggregation layer focused on bringing data into a knowledge base for the city, (ii) a solution for executing a large range of different data analytics with the support of process management tools, (iii) the formalization of Smart City APIs by which all the web and mobile Apps, and dashboards may access to the data and knowledge base with spatial and temporal reasoning and inference. R. Jalali *et al.* (Jalali *et al.,* 2015)presented general reference architecture for the design of smart cities and its services. According to authors, current Smart City frameworks for data collection and analysis do not take into account the citizen expectations. Specifically, in their proposed architecture, cloud computing is used to solve the big data issues and challenges; for them, cloud computing is the ideal technique to support this amount of information, and run many services on top of it and provides access to all the resources such as mobile devices, sensors, actuators, and tags any time, from any location.

Authors proposed architecture consists of three layers: (1) sensing layer that aims to collect data continuously or at random intervals based on three sensing resources in our architecture: (i) wireless sensor network (WSN), (ii) Radio-Frequency IDentification (RFID) and (iii) crowdsourcing, (2) network layer which provides the communication infrastructure to deliver the data from sensing layer to control layer and vice versa and (3) service and control layer that is responsible for retrieving data from data bases, applying some data mining algorithms to find interesting patterns in the data, registering and managing the services which are provided by multiple service providers. Unfortunallly, they forget the application layer which should interct with the service layer; authors also need to separate Servies and Control in their proposed architecture. In addition, their architecture allows developers, service providers and data miners to join the network and offer their services without security layer.A. Gaur*et al.* (Gaur *et al.,* 2015) proposed a Multi-Level Smart City architecture in order to facilitate the interaction between wireless sensor networks and information and communication technologies and to help for exploiting very large volumes of data and information using semantic web technologies and uncertain reasoning rules. The sensor applications are connected and utilized by different web applications for an intelligent operating condition. Specifically, they used a reasoning approach for knowledge extraction and information

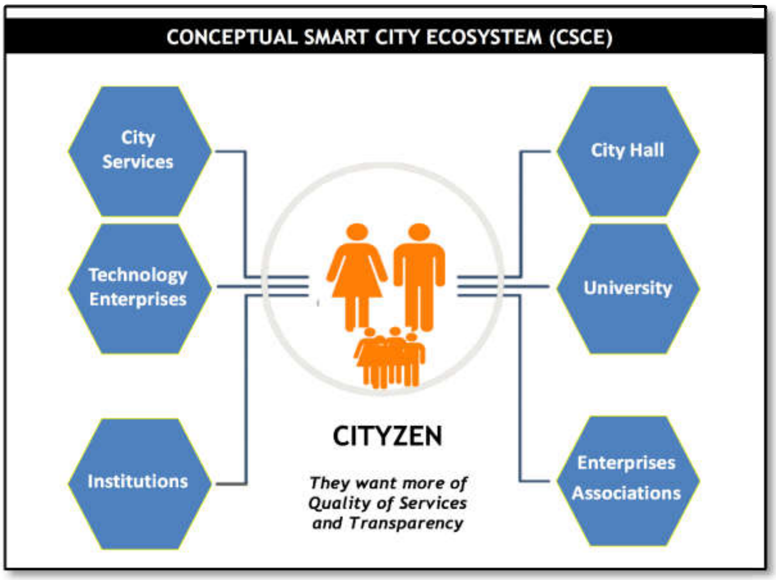

Fig. 1. Citizen-centric smart services in Smart City Ecosystem

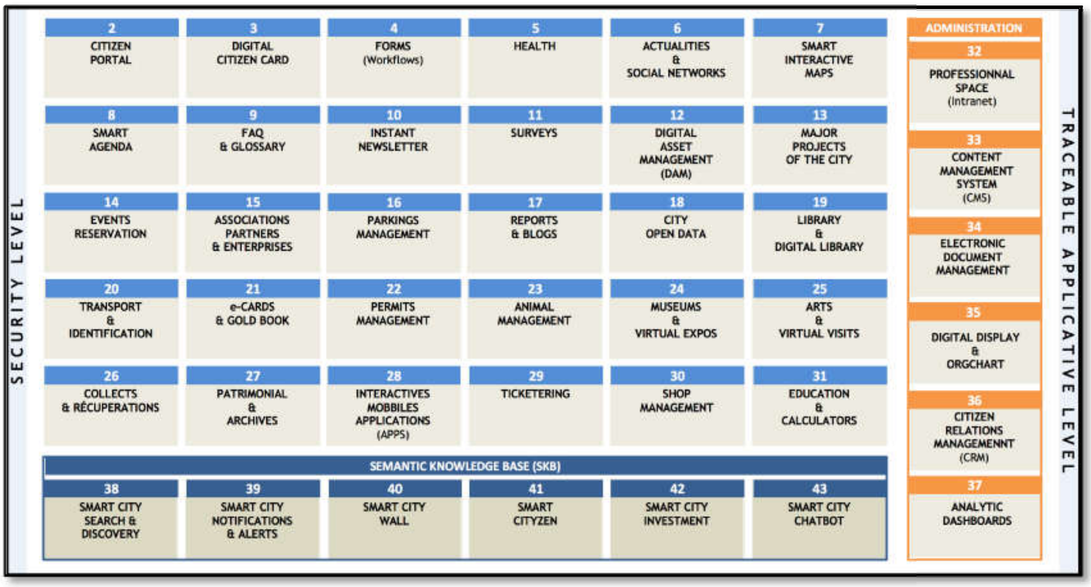

Fig. 2. Smart City Functionalities (Modules)

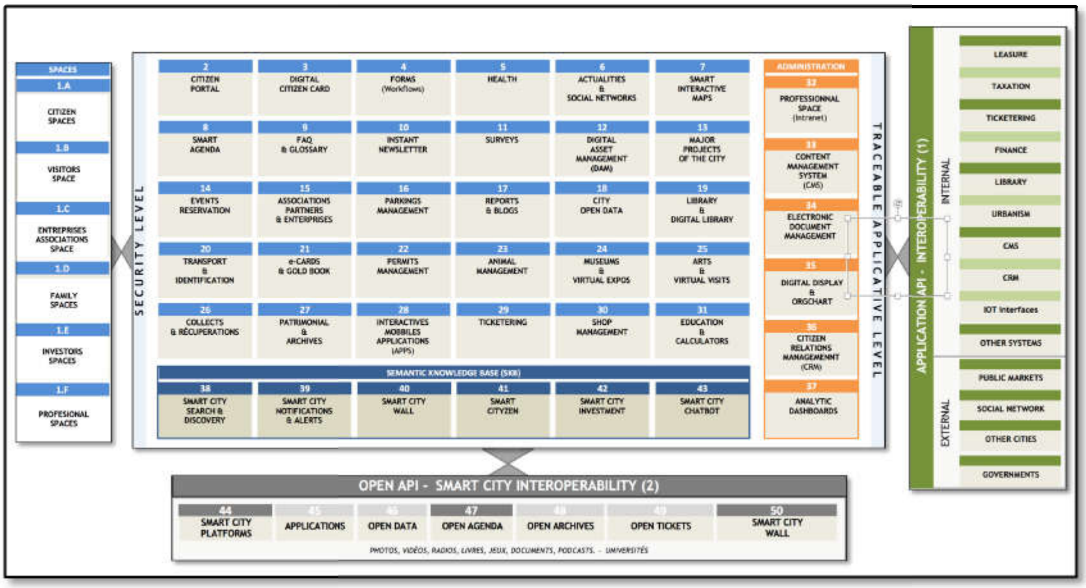

Fig. 3. Semantic Base Knowledge (SBK) and Interoperability

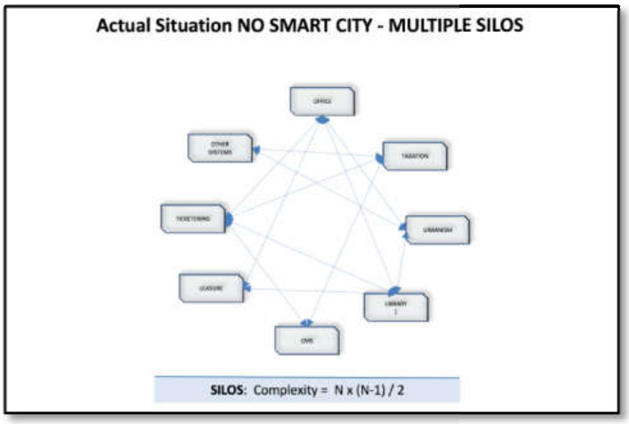

Fig. 4. MULTIPLE SILOS Applications Architecture

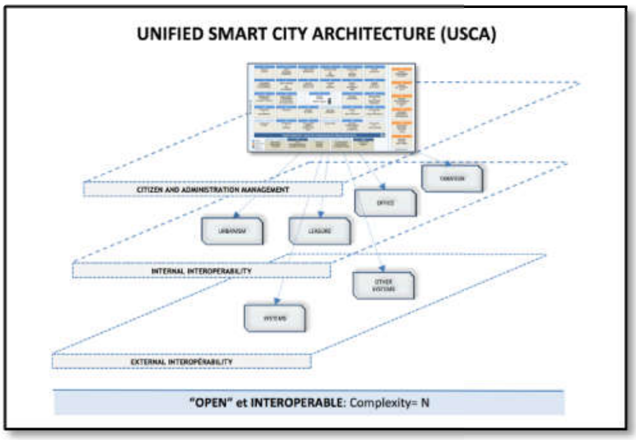

Fig. 5. Unified Smart City Architecture (USCA)

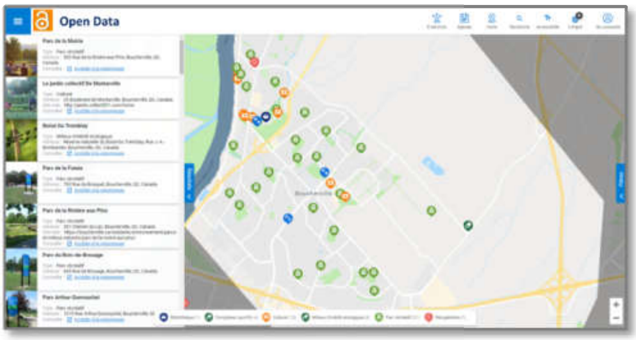

Fig. 6. LUCY Open Data (LOD) interface

Fig. 7. Smart Citynative smartphone applicationmain page

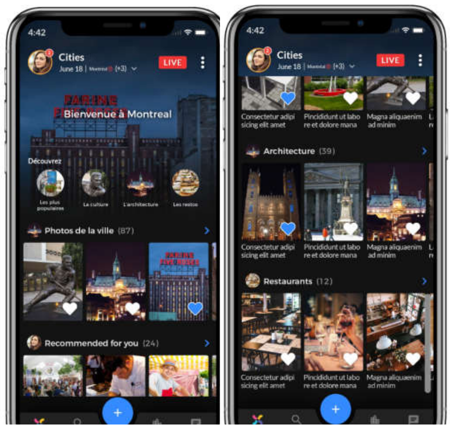

Fig. 8. Personas and MLM-based recommendation of events and restaurants for citizen "Julie" from Montreal

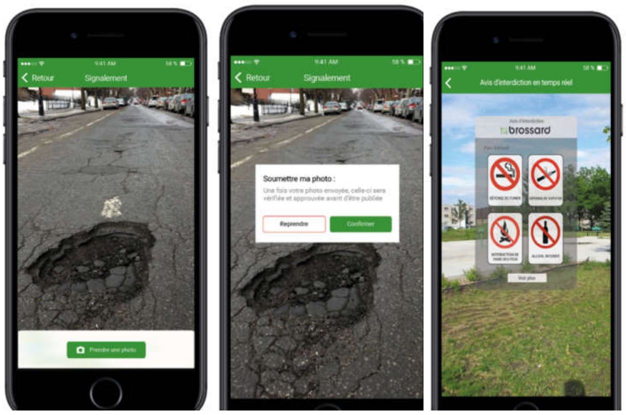

Fig.9. LUCY citizen complaint for city council

Fig. 10. SMRA section

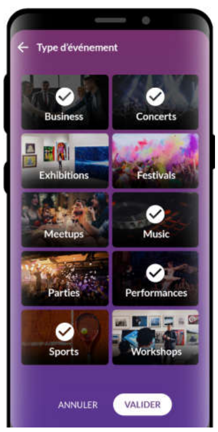

Fig. 11. LUCY citizen event preference selection

combination from different Smart City domains such as vehicle, health, home and environment domain and knowledge extraction. They identified the main elements of the Smart City architecture to be smart health, smart environment, smart energy, smart security, smart office and residential buildings, smart administration, smart transport and smart industries. Their proposed Smart City architecture consisted of four levels: Data collection (csv, tweets, database schemas and text messages), Data processing (converting the collected heterogeneous information into a common format), Data integration and reasoning (web ontology language, Dempster-Shafer, SPARQL) and Device control and alerts (input/output, messaging, alerts and warnings). Unfortunately, authors did not propose a prototype based on their architecture.V. A. Memos *et al.* (Memos *et al.,* 2018)proposed an Efficient Algorithm for Media-based Surveillance System (EAMSuS) in IoT network for Smart City Framework, which merges two algorithms introduced by other researchers for WSN packet routing and security, while it reclaims the new media compression standard, High Efficiency Video Coding (HEVC).

Specifically, the main goal of their proposal is to the efficient real-time video transmission from the sensor nodes – with the desirable gathered information from the environment – to citizens of the smart city and their devices (tablets, smart phone etc.), by applying improved encryption algorithm so as to ensure confidentiality and security of the transmission. In addition, their proposed algorithm contributes to the reduction of the memory consumption in the sensor nodes, while it also ensures a faster routing of the media sharing among the users of the smart city. Unfortunately, authors proposed architecture is limited to the security of media transmission over the IoT network of the Smart City.V. Zdraveski *et al.* (Zdraveski *et al.,* 2017)proposed architecture, guided by the ISO 37120 standard which includes 100 indicators for city services and quality of life, aims to acquire and process data from heterogeneous sensors and sources, implemented on the cloud. Their proposed architecture offers full data integration of various sensor networks, social networks, news, blogs, and other data sources to create a context-aware and energy-efficient IoT/big data/cloud platform and allows (i) improved city planning and forecasting, (ii) real-time reporting on infrastructure conditions, predicting and preventing problems, and deploying resources more efficiently, (iii) and two-way communications between government and people and effective citizen engagement by contributing to and accessing real-time city data.

Unfortunately, their proposed architecture is limited to Smart City data displaying using dashboards. According to the literature review, generic SCAI comprises of four layers: (i) sensing layer, (ii) transmission layer, (iii) data management layer, and (iv) application layer. Sensitive data protection is a key concern of any Smart City, thus security modules have been integrated to each layer. Data collection from physical devices is the main responsibility of sensing layer, which reside at the bottom of the architecture. Using various communication technologies, transmission layer carries data to the upper layers. Data management layer processes and stores valuable information that are useful for service provision offered by various applications at the top layer.

Smart City Application Architecture (SCAA): Smart City ApplicationArchotecture (SCAA)(Aguilera, Peña, Belmonte, & López-de-Ipiña, 2017) (Yeh, 2017) (Schleicher, Vögler, Dustdar, & Inzinger, 2016) (Bibri, 2018a) (Kummitha & Crutzen, 2017) (Han & Hawken, 2018) (Bibri, 2018b) (Kumar, Singh, Gupta, & Madaan, 2018) (Hashem *et al.,* 2016) (Zhang *et al.,* 2017) (Barns, 2018) (Kim *et al.,* 2017) (Mosannenzadeh *et al.,* 2017) (Nilssen, 2018) construction is one of the important parts for Smart City development. The application layer in the context of Smart City concept is the top layer of SCAI that mediates between urban citizens and data management layer. The performance of application layer highly influences user perspective and user satisfaction of Smart City operations, as it directly interacts with citizens. In general, all the Smart City solutions must cope with big data volume, variety, and veracity (Hashem *et al.,* 2016) (Bibri, 2018b). According to (Hashem *et al.,* 2016), the landscape of the smart technologies with big data and cloud computing, in which various smart applications exchange information using embedded sensor devices and other devices integrated with the cloud-computing infrastructure to generate large amounts of unstructured data.

These large amounts of unstructured data are collected and stored in the cloud or data center using distributed fault tolerant databases such as Not Only SQL (*Cassandra, Hbase, Mang DB, Couch DB, Volde-mort, Dynamo DB, and Redis*), which is used to improve a single service or application and is shared among various services. Most of the big data problems connected to the Smart City platform are related to real time data as the vehicle and human mobility in the city, energy consumption, health care, and IOT. According to (Silva *et al.,* 2018), the practitioners realized and claimed that encompassing advanced and sophisticated technologies is inadequate to attain user satisfaction in realistic smart cities. In order to attain these demands, more research work is encouraged in terms of design challenges, architecture, optimization of requirement analysis, security perspectives, and standards.

The Smart City architecture should be capable to take advantage of huge amount of data, at different velocity for exploiting and analyzing them (Badii *et al.,* 2017).In (Jalali *et al.,* 2015), authors introduced some application for Smart City paradigm. According to authors, Smart City approaches have the potential capacity for running many applications such as transportation, healthcare, smart environment, public safety, personal and social domain.For authors, the top three useful applications which can run on their proposed smart city architecture are transportation, healthcare and public safety.*Unfortunately, all the proposed applications of authors required IOT equipment for data collection.*J. M. Schleicher *et al.* (Schleicher *et al.,* 2016) proposed a specific foundations of a Smart city Operating System (SOS) that enables a larger Smart City App Lication Ecosystem (SCALE). Their SCALE allows stakeholders and citizens create applications within the smart city domain, focusing on what they want to know and freeing them of most of the hassles and hindrances that this technology currently faces. According to authors, the cloud computing paradigm is a natural fit for smart city applications, because it allows engineers to create distributed applications based on dynamic resource allocation and elastic scaling. They claimed that future Smart City applications must be designed as cloud-native, living applications that fulfill the following criteria, at a minimum: geographic awareness, adaptation, and resilience. *However, authors do not propose an example of application of Smart City.* F. Mosannenzadeh *et al.*

(Mosannenzadeh *et al.,* 2017) focuced their work on Smart energy city (SEC) which aims at assisting cities to exploit recent opportunities in technology and economy in order to provide citizenswith a better quality of life, while addressing urban energy challenges such as climate change, shortage of energy resources, and inadequate and deteriorating energy infrastructure. They introduced a list of practical smart energy solutions for decisionmakers in each SEC domain of intervention: (i) hard domain that consistes of the sub-domains of buildings and districts, transportation and mobility, energy and ICT infrastructure, and (ii) soft domain that includes solutions in collaborative planning, consumer behavior management, and energy and data management; soft domain solutions are applicable on all spatial scales (building, block, district, or city-wide level). *Unfortunately, authors do not proposed a prototype of application for Smart City in terms of Smart energy management in the city.*U. Aguilera *et al.*(Aguilera *et al.,* 2017) introduced the Internet-Enabled Services (IES) Cities platform, whose goal is to ease the generation of citizen-centric apps that exploit urban data in different domains in contrast to the holistic ‘‘smart city in a box’’ solutions.

Their vision is to provide a common access mechanism to the heterogeneous data sources offered by the city in order to reduce the complexity of accessing the city’s data whilst bringing citizens closely to a prosumer (double consumer and producer) role and allowing to integrate legacy data into the cities’ data ecosystem. In the proposed IES Cities, citizens used the player or the platform’s web infrastructure to discover applications and data sources provided by the city or other third-party providers. Application entities of proposed IES Cities platform present registered applications where each service can be associated with a certain geographical scope to allow citizens to discovery applications based on the user’s detected location, in addition to a basic keyword search. *Authors do not propose applications to make cities smart.* M. I. Pramanik *et al.* (Pramanik, Lau, Demirkan, & Azad, 2017) proposed a specific application of Smart City, Smart health in order to help hospitals to achieve smart healthcare using big data and based on three broad technical (3T) branches: Intelligent Agents, Machine Learning, and Text Mining. The Intelligent agents collects input and interacts with its surroundings, executing some given tasks in order to achieve desired goals. Machine learning is being used to analyze heterogeneous health data (e.g. X-ray re- ports, ECG reports, tomography reports, temperature, pulse, and blood pressure reports) and to increase the performance of clinical parameters and the combinations of the variety of medical prognoses such as the prediction of disease progression, decision support for therapy or surgery, knowledge extraction from emerging research and practice, and overall healthcare system management. Text mining is used in healthcare for information retrieval and representation from unstructured data in the context of medical research and services.

Smart City and Machine Learning Model (SCMLM): New data forms (big data) exist which lead to a huge data size on the internet due to the rapid change in technologies. To exploit this new data forms, data science seems to have the solution. Data science is the combination of different scientific fields that uses data mining, machine learning, and other techniques to find patterns and new insights from data(Chin, Callaghan, & Lam, 2017)(Elhoseny, Elhoseny, Riad, & Hassanien, 2018)(Y. He, Yu, Zhao, Leung, & Yin, 2017). (Mahdavinejad *et al.,* 2018) (Mohammadi & Al-Fuqaha, 2018) (Mohammadi, Al-Fuqaha, Guizani, & Oh, 2018) (Souza, Francisco, Piekarski, & Prado, 2019). These techniques include a broad range of algorithms applicable in different domains. In addition, the big data in smart cities exhibits a new characteristic, called geo-distribution. This new dimension of big data requires that the data needs to be processed near the data harvesting devices at the edge, instead of the data centers in traditional Cloud computing paradigm. It is necessary to offer low latency responses to protect the safety of critical infrastructure components. Fog Computing is a suitable paradigm by extending the Cloud Computing to the edge of network and that researchers investigate and develop novel and high performance computing architectures. M. S. Mahdavinejad *et al.* (Mahdavinejad *et al.,* 2018) presented a machine learning a survey that would help Smart City services providers to obtain a deep and technical understanding of machine learning algorithms, IoT applications, and IoT data characteristics along with both technical and simple implementations. Authors claimed that to reach suitable decisions for smart data analysis, it is necessary to determine which task should be accomplished out of structure discovery, finding unusual data points, predicting values, predicting categories, or feature extraction.

For example, a Support Vector Machine (SVM) algorithm is implemented on the Aarhus City smart traffic data to predict traffic hours during one day. J. T. Souza *et al.* (Souza *et al.,* 2019) presented a review regarding data mining (DM) and machine learning Model (MLM) approaches adopted in the promotion of smart cities in order to encourage governmental agencies and companies to develop smart cities; that is essential to assist in the sustainable development goals. According to authors, despite the interest in promoting smart cities, there is still a lack of consensus in current literature about the real effects of these techniques for cities. In addition, most research explores specific issues, not focusing on the role of DM and MLM in smart cities. They claimed that, as far as they know, no published articles have addressed the different DM and ML techniques needed for this subject.H. Elhoseny *et al.* (Elhoseny *et al.,* 2018) proposed a Smart Learning Framework for smoothly adapt the traditional eLearning systems to be suitable for smart cities applications; their framework provided a conceptual model for Big Data learning Analytics platform. The proposed smart learning framework combines both of e-learning worldview with the advantage of big data analysis and coordinates three layers of various innovation structures: smart information transmission layer, smart devices layer and smart application. Unfortunately, author proposed framework only treat the data to extract specific information as an ELT (Extract, Load, Transform) framework and used existing machine learning algorithms for eLearning. J. Chin *et al.*(Chin *et al.,* 2017) explored the potential of Machine Learning Model (MLM) and Artificial Intelligence (AI) to develop a personalised services for Smart Cities using Internet of Things (IoT) and Big Data. They compared the performance (accuracy, trustworthy and speed) of four well-known MLM classification algorithms (Bayes Network, Naïve Bayesian, J48 algorithm, and Nearest Neighbour) to understand the behaviour of the users in order to o adapt efficiently, to the user’s changing behaviour over time. They investigated the relationships between weather and short cycling journeys. Unfortunately, their proposal is just a study and do not present useful application to help cyclists in London.

In conclusion and based on the SCM proposed in(Yin *et al.,* 2015), our proposed SCM take into account the three of the four essential domains: Persons (Citizens and Visitors), Business (Associations and Enterprises) and Environment; however, few approaches focused their works on citizen and visitor side (Jalali *et al.,* 2015). The objectives of SCMs do not only focus on the description of the concept, but rather on their possible use as a support for decision making; very few of the SCMs were applied to real cases. SCAI goal is data management and consists of four main steps: (1) data generation and collection, (2) data transmission, (3) data processing and (4) data interpretation. Finally, existing Smart City projects do not propose a platform of several machine learning-based features which enable citizens to take advantage of a smart assistant based on the smart applications of the city. Finally, most research do not focus on the role of DM and MLM in smart cities (Souza *et al.,* 2019).

Smart City Model and Architecture: « Smart City » is a term to describe a municipal ecosystem where the citizen, the technologies, the innovation and the collaboration are together for the creation and the acceleration of renewed local services and to get a better life for all the citizen. Smart City, defined a city using a smart and connected ecosystem, the technologies and communication to get a better life for citizen and to reduce the cost of the utilization and the administration for the city. What are the main keywords associated with the Smart City concept:

- Collaboration: In the Smart Cities, the Cities are open minded. They share their data and their projects to deliver better centric-service citizens based.
- Innovation: The smart city has to facilitate the citizen, the enterprise, association and administrations to imagine new organizations to deliver new and unexpected from the city to their citizens.
- Participation: The city is not a real smart city if his ecosystem is not collaborative involving citizen, enterprise, and all other participants. The participation is the key to good governance into the Smart City.
- Optimization: The cities have developed in the last decades number of complex rules, these rules must be simplified to the citizens. In the **Error! Reference source not found.**, we show the Conceptual Smart City Ecosystem (CSCE):
- Here, are some of the objectives of the Smart City

Mobile Applications:

- To communicate efficiently between all stakeholders.
- To facilitate the access to all stakeholders from anywhere and according to their interest with a user friendly and ergonomic design.
- To Get stronger relationship with the citizen using interactivity and a citizen space to keep track of their interests and past choices.
- To optimize the number, quality and efficiency of the services for all citizens.
- To facilitate the sharing of information between all the stakeholders.
- Toorganize all information and events to make it easily available for citizens.
- To involveactively as much as possible all skate-holders of the city.
- To secure all data and confidentiality relative to citizen and the city.
- To promote the brand of the innovative city.
- To facilitate the job creation using innovative functionalities of Smart City.

In the Error! Reference source not found., the Smart City Ecosystem is composed of five elements:

- Citizen Spaceis personalized according to the citizen interests.
- Functions dedicated to the citizen.
- Functions dedicated to the administration of the city.
- The Semantic Knowledge Base (SKB) of the Smart City.
- The Cloud based infrastructure connected and interoperable.

- The Citizen Spaceis the main location for the citizen and his city. It assemble the key elements for the citizen, it is the agenda of the citizen for his city and more, the center of his data;it is all his preferences.
- The Smart City Modules for Citizen. The next figure representsthese modules includingthe Citizen Space:
- Personal and Professional Spaces, Citizen Portal, Digital Citizen Card, Form (Workflows), Health, Actualities&Social Network, Smart Interactive Maps, Smart Agenda, FAQ & Glossary, Instant Newsletter, Surveys, Digital Asset Management (DAM), Large City Projects, Location, Place Reservation, Associations, Partners& Enterprises, Parkings, Reports & Blogs, Open Data, Library & Digital Library, Transport &Observations, e-Card&Gold Book, Permits, Animal Management, Museums&Virtual Expositions, Art &Virtual Visits, Collects & Recuperations, Patrimoine& Archives, Mobiles Interactives Applications, Ticketing, Boutique Management, Education & Calculators.
- The Smart City Modules for Administration of the City. The next figure represents these modules:
- Professional Space (Intranet), Content Management System (CMS), Electronic Document Management, Digital display&OrgChart, Citizen Relationship Management (CRM), Analytic Dashboards.
- The Semantic Base Knowledge (SBK) is the knowledgeable data of the city availablefor citizen. SBK allows to do recommendation to the citizen, the visitor, the enterprisesand the other stakeholders of the city.SBK included data from the city, but also contents, events and geo-localization:
- Citizen Semantic Search, Informational Survey, Virtual Garage Sales, Smart Parking&Virtual Display and Smart Tourism.
- The Cloud based Interoperable Technology Infrastructure (CITI)allows to the citizen to access to all services of the city anywhere at any time.
- It is the mobile city, accessible at anytime and geo-localized for the citizens according to their interests.
- Two APIs are required: The applicative API – Interoperable (1) andthe API « open » - Smart City interoperability (2):

- Smart City Platforms, External Applications, Open Data, Open Agenda, Open Archives, Smart Citizens, Destination Cities & Museums.

There is two models of Application Architecture in the cities : 1) MULTIPLE SILOS (see Fig.): a traditional situation where there is multiple software suppliers delivering multiple functionalities in isolated, not-connected silos: the city has sectioned many software suppliers in different area of specialtyand, using limited API, transfer information from one silo to some others one and 2) UNIFIED SMART CITY ARCHITECTURE (USCA) (see Fig.): one unified platform using APIs to connect different suppliers to the smart city including multiple apps to answer the needs of the citizen and the administration of the city, it is a ERP (Enterprise Resource Planning) for the Smart City. USCA includes a Citizen Space who is the kernel of the Smart City allowing full communication between Citizen and City, but between City and Citizen but furthermore between citizens themselves. The level of the complexity between the two architectures is completely different. For the traditional approach (MULTIPLE SILOS),the complexity is around N x (N-1)/2 and for the Smart City approach (USCA, the level of complexity is around à N for an integrated approach. Our vision of the Smart City Ecosystem has three levels: (1) Citizen and City Administration, (2) Interoperability of the Internal City Systems and (3) Interoperability of the External City Systems.

Prototype Applications: The Smart City mobile application platform is a part of a project of Smart City involving some cities of Canada or Europe. This project has been deployed on a limited network we introduces new processes for the smart harvesting of data and their management and its related services. Therefore, we have validated our Smart City Model and Architecture taking into account the different roles: citizens, visitors, associations, businesses, councils and service providers. Notice that all suggested lists are based on the users Personas which is the user's interest; we applies MLM to affine the lists.

City council participation: We have allowed the participation of city councils as service consumers and data providers in order to validate our Smart City Model thanks to the participation of four different cities with different degrees of maturity in their open data strategy. For example, while some cities already had previous experience on providing data and urban applications to their citizens and for other to take results of the project to start and take impulse on their Smart City strategy.

Smart City platform proof-of-concept: In this section, we present the two applications used by citizens in the context of Smart City: web-based version and native smart phone application. We develop a web-based version to give the opportunity to all stakeholders of the cities who do not have smart phone or who are not used to using new generation mobile applications to take advantage of certain functions of the smart city such as the recommendation of the events. Mostly, applications which do not use real time geolocation are implemented in the web-based version. The main characteristic of the native smart phone application is the features based on real time geolocation such as Augmented Reality (AR), Geolocation-based Matching Concept (***LUCY-GMC***) use to match contents and city stakeholders (citizens, visitors, businesses, associations, city councils) or city stakeholders between them.

Smart Cityweb-based version: The web-based version includes over a hundred pages that take into account the needs of the city stakeholders. The web-based version home page that allows users to select their stakeholder profile in the city (Citizens, Visitors or Enterprises). The selection of stake-holder profile in the city allows to adapt the contents, the services and the events of the city in order to increase the user experience. It offers to citizens many features in their personal space. Citizens may receive their personalized newsletter, receive notices and notifications, check their smart agenda, check their municipal bills, consult leisure activities and participate of the city surveys. Fig. shows a capture of the web interface that is available to end-users such as citizens and services providers to access the information provided by LUCY Open Data (LOD). For example, citizens may search and discover places such as parks by their location inside the city or using preferences expressed as keywords, enabling them to select those parks that are more relevant to their needs in their city.

Council administrators use the LOD to publish their datasets, and to gather usage statistics about them. In addition, the LOD also enables council administrators to validate and ensure the quality of applications and datasets created and published by third-party participants, enabling those external participants to be part of the public administration Smart City's vision. Services providers are provided with a list of public datasets, each dataset has an associated data model and all the configuration details that they needs to develop services for city stakeholders. Several of the data are made available by LOD; for example, air pollution data is gathered from several air quality measurement stations, which measure CO, O3, NO2, PM2.5, and PM10. It retrieve information from the DB pedia SPARQL endpoint.

Smart City native smart phone application: The native smartphone application uses two mains concepts: LUCY-GMC and Swipe style. This section present some features of native smartphone application which provides most of the functionalities of the web-based version.

Fig. shows the home page of native smartphone application. After the login session, APPS displays the different smart city application section: Cities, My space, Smart Agenda, Marketplace, Game, Daily knowledge, Social Network and LIVE. APPS native smartphone application combined city and social features to offer to stakeholder a unique smart city space. Fig. presents the cities page for the citizen. Notice that it is for the citizen a hub of cities. That allows a citizen to select several cities for his/her personal space.

and restaurants for citizen "Julie" from Montreal

The citizen is notified for all activities and events of these cities.In Fig. , LUCY suggests the events to citizen according to his/her location, his/her personas, and his /her historical behavior on the application using our MLM algorithm called, Social Matching Recommendation Algorithm (SMRA). The feature, shown in

Fig., uses open data and smart city data to get an overview of the reports and faults occurring in the city's public infrastructure. This feature of the native application uses semantic data with technical knowledge of the query and data modelling language (SPARQL and RDF) to pre-process data before send them. LUCY AR feature allows to visualize the city prohibition notice of selected parks superimposed on the real phone-view as well as guide users through the park with its route displayed in real time.The native smartphone application combined city and social features.

Fig. presents LUCY social home page. In the top of the page, the native APPS presents a set of suggestions (events, products, job, restaurants, bar, place of interests, and so on) to the citizen based on its Social Matching Recommendation Algorithm (SMRA). In order to increase the SMRA performance, the prototype uses the swipe style to allow users to select the contents they like.

Summary and future work

We have presented our Smart City Model, Architecture and Applications based on components which interoperate between them to offer smarter services to citizens. The proposed model shows that multiple layers are needed to explain Smart City Applications and different services delivered to citizen. Notice that the proposed model is citizen-centric; citizen is the central element of the Smart City including the understanding that the citizen has his own interests and behavior. Based on the proposed model, we prototype a multi-tenant platform, called LUCY which mainly used user-created content (UCC) concept. Our plan for future work includes the algorithm to recommend to citizen what to do this evening, how to management his smart agenda according to his personas and specific interests. We will used our specific MLM ecosystem to prototype and evaluate the impact on the citizen life. SMRA (Social Matching Recommendation Algorithm) will be presented in details in our future papers. Fig.shows the citizen page for interests and preferences setting.

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