Internet of Things and Big Data Analytics for Smart and Connected Communities

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***Abstract*—This article proposes the concept of ”smart and connected communities (SCC)”, which is a unified framework integrating smart cities and beyond. Different from big cities, small communities call for culture preservation in addition to revitalization. IoT technologies could potentially serve this need. This article develops an IoT architecture, and choose best IoT enabling technologies, and IoT services, applications, and standards, towards this goal. The purpose of this article is to introduce a novel concept called ”SCC” whose vision is to improve livability, preservation, revitalization, and sustainability, of a community, different from so-called smart cities. In this article, we shed light on the opportunities and challenges of applying IoT and big data analytics to culture preservation and revitalization of SCC. We expect that the intelligent use of IoT and big data analytics could breathe new life into traditional, close-knit culture of SCC. As a case study, we present TreSight which integrates IoT and big data analytics for smart tourism and sustainable cultural heritage in the city of Trento, Italy.**

***Index Terms*—Internet of Things, Big Data Analytics, Smart and Connected Communities, Smart Cities, Smart Tourism, Sustainable Cultural Heritage.**

I. Introduction

MOTIVATED by growing global needs to create more comfortable urban spaces as world urbanization continues to grow as the global population is expected to double by 2050, Smart Cities are emerging as a priority for research and development across the world. Smart cities open up significant opportunities in several areas, such as economic growth, health, wellness, energy efficiency, and transportation, to promote the sustainable development of cities.

Internet of Things (IoT) is a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies[1]. It is envisioned that environments with trillions of device and information objects are connected via networks. The vision of the IoT is a smart world consisting of smart devices, smartphones, smart cars, smart homes, smart cities [**?**]. With IoT, physical objects are able to be seamlessly integrated into an Internet-like system so that the physical objects can interact each other and to cyber-agents in order to achieve mission-critical objectives [2]. IoT is a networking infrastructure for cyber-physical systems (CPS), which are engineered systems that are built from, and depend upon, the seamless integration of computational algorithms and physical components [3]. Advances in CPS will enable capability, adaptability, scalability, resiliency, safety, security, and usability that will far exceed the simple embedded systems of today. CPS technology will transform the way people interact with engineered systems – just as the Internet has transformed the way people interact with information. New smart CPS will drive innovation and competition in sectors such as agriculture, energy, transportation, building design and automation, healthcare, and manufacturing.

With big data analytics, we could continuously improve the collection, aggregation, and use of data to improve the life of their residents by harnessing the growing data revolution, low-cost sensors, and research collaborations, and doing so securely to protect safety and privacy.

One important application of IoT and big data analytics is smart cities [4], which will use the power of ubiquitous communication networks, highly distributed wireless sensor technology, and intelligent management systems to solve current and future challenges and create exciting new services [5]. The vision of IoT for smart cities is to improve the ’livability’ of cities[6]. However, 46 percent of the world’s population lives in rural areas, rather than urban areas [7]. In the United States, almost 53 million people live in small towns with populations of fewer than 25,000 [8]. The major differences between a city and a town lie in three aspects. Firstly, they differ in size, i.e., cities are bigger than towns. For example, in West Virginia, a U.S. state located in the Appalachian region of the Southern United States, out of 1,850,000 people, there are more than 1,600,000 people living in small towns and the rest living in 5 large cities with populations of more than 25,000. Secondly, they differ in history, i.e., typically, cities are modern and fast-changing while towns are historic and traditional, even ancient and stable. In China, there are many ancient towns whose history could be traced back to 2,000 years ago but Jamestown, the oldest town in the United States, has a history of 407 years only. Thirdly, they differ in terrain. For example, in the view of terrain, the United States has vast central plain, mountains in west, hills and low mountains in east, rugged mountains and broad river valleys in Alaska, and rugged, volcanic topography in Hawaii. Furthermore, the life senses of residents in cities and towns are dramatically different. In the city, people are more likely to a busy, fast-paced, and rapid-

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changing life-style; while in the towns, residents, especially in the historic areas, are more like to keep their traditional high sense life style and the culture from their grandfathers.

Smart towns are facing serious challenges, including declining downtowns and incompatible development in historic areas/loss of community character, loss of natural areas and open space, suburban-style large-lot growth at city edges, limited housing choices, lack of transportation options, limited planning capacity, and opposition to regulations [9].

Therefore the IoT architecture, protocols and technologies for smart cities could not be applied directly to towns and then to the communities. There is an urgent need to investigate how the IoT could be applied to towns to support the Smart Town vision which is to improve livability, preservation, revitalization, and sustainability, of a town [10]. Different from the focus of smart city on the needs of living in the present, i.e., livability, a smart town is envisioned to integrate the needs for remembering the past (preservation and revitalization), the needs of living in the present (livability), and the needs of planning for the future (sustainability) [10]. The application of IoT technologies for a smart town is to remember the past, live in the present, and plan for the future, of a town.

In this article, we present the concept of ”Smart and Connected Communities (SCC)”, which are a unified framework integrating big cities, small towns, and beyond. Advances in the effective integration of networked information systems, sensing and communication devices, data sources, decision making, and physical infrastructure are transforming society, allowing cities and communities to surmount deeply interlocking physical, social, behavioral, economic, and infrastructural challenges [11]. These novel sociotechnical approaches enable increased understanding of how to intelligently and effectively design, adapt, and manage SCC [11]. The purpose of this article is to identify the opportunities and challenges when the IoT and big data analytics technologies are applied to SCC.

This article is organized as follows. Section II presents a vision of SCC, and highlights the differences of SCC from smart cities: preservation, revitalization, and sustainability. Section III and Section IV presents the opportunities brought by IoT for SCC, including IoT architectures, enabling technologies, services, applications, and standards. Section V presents the opportunities brought by big data analytics for SCC. Section VI presents TreSight, a case study of IoT and big data analytics for smart tourism and sustainable cultural heritage in the city of Trento, Italy. Sections VII describes the challenges of applying IoT and big data analytics to SCC. Section VIII concludes this paper.

II. The Concept of Smart and Connected Communities

The concept of ”SCC” was proposed in [10] for applying IoT technologies to preserve and revitalize historic towns with Appalachian traditional culture in West Virginia. It is argued that IOT technologies and Appalachian traditional culture are not polar opposites and envisioned that the application of IOT technologies could preserve and enhance culture, craft and cool towns. More importantly, it is demonstrated how the smart and subtle use of IOT ”embedded” technologies could breathe new life into Appalachian traditional, close-knit culture and communities and how IOT technologies could create exciting new products and services based on ”new Appalachia” culture and expand economic opportunities through entrepreneurship. Further, the vision of ”SCC” is to improve livability, preservation, revitalization, and sustainability, of a community [10], as shown in Figure. 1. Different from the focus of smart city on the needs of living in the present, i.e., livability, a smart and connected community is envisioned to integrate the needs for remembering the past (preservation and revitalization), the needs of living in the present (livability), and the needs of planning for the future (sustainability) [10] . The application of IoT technologies for a smart and connected community is to remember the past, live in the present, and plan for the future, of a community.

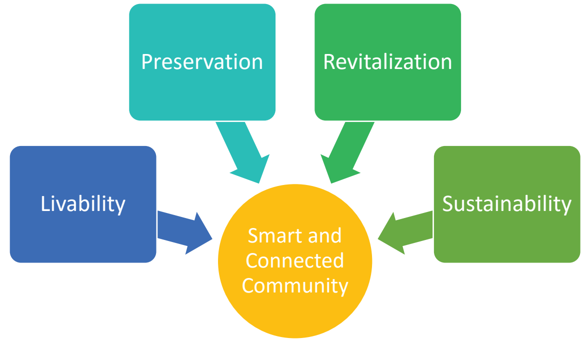

Fig. 1. *The Vision of Smart and Connected Communities.*

A. Livability

The vision of IoT for smart cities is to improve the ’livability’ [6], which is among four elements of the vision of IoT for SCC. There are six principles of livability [12]: (1) Provide more transportation choices to decrease household transportation costs, reduce our dependence on oil, improve air quality and promote public health; (2) Expand location- and energy-efficient housing choices for people of all ages, incomes, races and ethnicities to increase mobility and lower the combined cost of housing and transportation; (3) Improve economic competitiveness of neighborhoods by giving people reliable access to employment centers, educational opportunities, services and other basic needs; (4) Target federal funding toward existing communities - through transit-oriented and land recycling - to revitalize communities, reduce public works costs, and safeguard rural landscapes; (5) Align federal policies and funding to remove barriers to collaboration, leverage funding and increase the effectiveness of programs to plan for future growth; (6) Enhance the unique characteristics of all communities by investing in healthy, safe and walkable neighborhoods, whether rural, urban or suburban.

B. Preservation

Heritage constitutes a source of identity and cohesion for communities disrupted by bewildering change and economic instability [13]. Heritage can be classified into two categories: cultural heritage and natural heritage. Further, cultural heritage includes tangible culture (such as buildings, monuments, landscapes, books, works of art, and artifacts), and intangible culture (such as folklore, traditions, language, and knowledge). It is obvious that intangible cultural heritage is more difficult to preserve than tangible cultural heritage. Natural heritage includes culturally significant landscapes, and biodiversity.

One of the missions for SCC is to preserve culture heritage for these traditional towns by using IoT technologies and big data analytic tools. [13].

C. Revitalization

Many small towns are interested in engaging in revitalization efforts to renew downtown areas and restore them to their former prominence as a center of community activity. Residents in small towns generally are pride of some special things from their grandfathers. Indeed, there are many challenges which are unique to small towns. Different from large cities, a common difficulty for small towns is a lack of resources and expertise to support and implement the revitalization [14].

D. Sustainability

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs [15]. Three pillars of sustainability are its social, environmental, and economic aspects. Sustainability is not limited to mitigating climate change, i.e., managing the carbon dioxide cycle and increasing sustainable energy sources. Rather, there are other important sustainability challenges, such as water management, improved urban planning, supporting biodiversity, and food production [16].

III. IoT Architecture for Smart and Connected Communities

This section aims to a general architecture for IoT implementation in smart towns. Intelligentalization is the core challenge for developing IoT architecture, addressing IoT services, and specially preserving culture to realize smart towns.

An integrated smart system is just like a human who has his own sensing systems, nervous system, store system, and his own brain for decision-making. The function architecture of the IoT for smart towns involves four different layers: sensing/responsing layer, interconnecting layer, data layer, and services layer, as shown in Fig. 2.

- The sensing/responsing layer is the outmost layer of IoT, which is the perceiving and responding system. The layer includes all kinds of "Things" connected to the IoT, mainly varieties of smart devices. The primary functions of this layer include 1) perceiving the state changes of the thing itself or the environment, and transmit the information to the interconnecting layer with specific format; 2) receiving commands from core layers, and making responses according to commands. Currently, researches on this layer focus on the sensing related communicating techniques, mainly addressing on the RFID technology and sensor network systems.

  There would be trillions of smart devices in a smart town. These interconnected devices are endowed with different tasks. They can be classified into three categories according to their functions.
  - Sensors. A sensing object has relative simple function– only perceiving the state of its environment, such as temperature, location, and etc., and submitting the captured data to the control node. Generally, such a sensing device could make neither any decision nor any action actively.
  - Actors. An actor object can receive the command from the control node, and make an action according to the command.
  - Sensor/Actor. A sensing/actor object (SAO) can not only capture and send the environment information but also make an action according to the received command. In addition, some SAO might have a micro decision module, which can make some decision for its next action according to the local knowledge base and the information captured from its context.
- The interconnecting layer is the connecting systems, including the current internet and mobile internet. Just like the human nerves system, its main mission is data transmission and information exchange among different devices and different domains. The rapid development and the maturation of the current internet technologies provide a solid foundation in communication technology.
- The data layer is the "brain" of the smart towns. Regarding to demands from services layer, for example, smart lighting in bad weather, the intelligent decision system automatically decides next actions with the support of the knowledge base and realtime data analysis. The main functions of this layer are listed as follows.
  - Storing the massive, trivial, and heterogeneous data

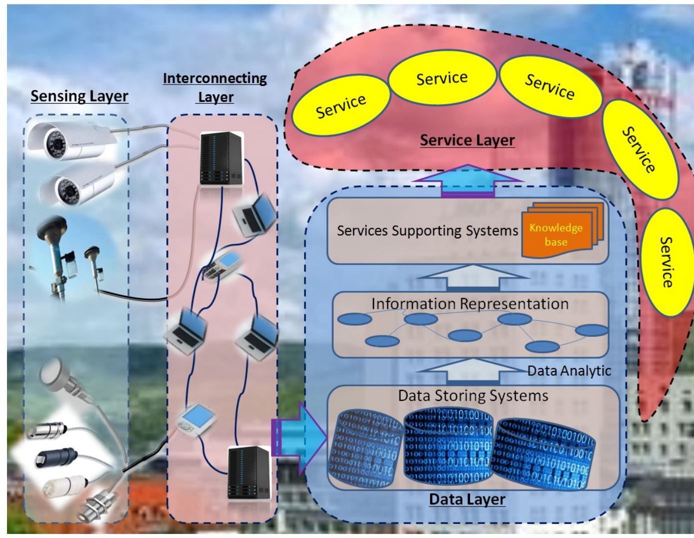

Fig. 2. *Function Architecture of Internet of Things for Smart and Connected Communities.*

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generated from variety kinds of monitoring devices in the sensing layer. For a smart town, the sensing data would be much big. These sensing data is the reflection of the events occurred in a smart town. How to organize and how to store the big data in efficient and effective ways would be hot topics for researchers and practitioners[17].

  - Extracting useful information from the big sensing data and representing the meaningful information in reasonable and efficient ways. The value density of the big data is really low regarding to the volume though the information precious, i.e., most of the big sensing data from smart town are meaningless. Indeed, most vital data are generated when there are some interesting events occurs in physical world. How to extract these interesting events (which occurs in physical world) and their internal relations are primary for data analysis. These events information are the most precious property for a smart town to make right decisions on right problems [18], [19], [17].
  - Decision making and service supporting. The services supporting systems would provide right information, right reasons, and right decisions according to the demands of the service (application) layer. Right information is provided by tools of data mining and analysis. Right reasons would be replied on the knowledge base which includes a large set of reasoning rules and a set of cases and laws for analogy reasoning [20][21]. Right decision should be made automatically by smart systems according to right information and right knowledge.
  - Knowledge maintaining and managing. Knowledge base should be updated in real time with new knowledge, which can be provided by domain experts or retrieved by analyzing volumes of history cases with knowledge mining tools[22]. In addition to replacing the outdated knowledge with the new ones according to the evolution of the IoT, it is also necessary to maintain the integrity and the consistency of the knowledge base.

- Service layer, namely application layer, can provide varieties of services for small towns. This layer is the interface between IoT intelligent systems and end users in the town. All services depend on the service supporting systems. The main services can be classified into two types: common services for all small towns and featured services for specified towns. There are dozens kinds of common services for a smart town, inluding intelligent infrastructure services, smart environment services, Water Services, smart Metering Services like smart grid and tank level,emergency and security services, retail services, eHealth services, and smart homes services.

  Featured services would only be provided for specified towns according to the featured culture and social folks. In the process of urbanization of last decades, for example in China, some of the traditional featured cultures and ancient folks are facing the inherit problems. It is a primary task for IoT technologies to protect these folks and arts in small towns. The following are some example services.

  - Folk arts protecting services. Most small towns all over the world have their own localized folk arts, for examples, in China, traditional acrobatics in Wuqiao of Hebei Province, L*ü* opera in Zhangqiu of Shandong Province, and etc. For these traditional folk arts, there are two different technologies to protect them. First of all, wearable sensors can be embedded in clothes for actors. These sensors can record all posters information during training and shows. The sensing data from masters and students can be compared and analyzed to find reasonable ways to play and find the best methods for training. Secondly, cameras can record the famous Master's show from different views. These data can be used to reproduce the show for audience in a real way by using 3D virtual reality technology.
  - Handicraft arts protecting services. Handicraft arts are another kind of traditions for small towns. For example, the Kite Festival in Weifang of Shandong Province, the Paper-cut arts in South China, and etc. The handicraft arts can be protected just like the Folks arts.
  - Traditional food-cooking protecting services. There are many different kinds of featured food cooking arts all over the world. For example, localized Wine-making and local cake-making arts in many different towns. Monitoring devices and sensors for air conditions, temperature, and humility can be used to record the whole making process. It would be useful to protect the food-making arts of local towns.
  - Protecting services for Historical building and cultural relic. Varieties of sensors can be used to monitor the vibrations and material conditions in buildings, bridges and historical monuments for the purpose of protection.

IV. IoT Enabling Technologies for Smart and Connected Communities

According to the architecture of the IoT for smart and connected communities, enabling technologies include sensing technologies, networking technologies, and data technologies. With the quick development in the decades, sensing technologies and networking technologies have been more and more mature, which can enable the sensing layer and interconnecting layer. This has prompted the rapid growth of various sensing data. Meanwhile, there are many challenges in data technologies, including storage, organization, management, and analytic, etc.

A. *Sensing Technologies for Smart and Connected Communities*

Sensing technology aims to feeling status and changes of the target environments or objects by retrieving relevant data.

Varieties of sensing technologies have been emerged in the last decades, such as optical sensing technology,Radio location and tracking technology (like RFID), Radar imaging technology, Magnetic sensing technology, air monitoring technology, noise monitoring technology, temperature and humidity detecting technologies, and etc.

B. Internet Technologies for Smart and Connected Communities

Internet of Things is the extension of the current Internet by connecting all possible devices including all kind of sensors. Successful Internet technologies would be the primary body for IoT connecting technologies. In the SCC IoT, each object with sensing chips can exchange data with specified format with other things or servers in the Internet. IPv4 is the main addressing technology for the current Internet. However, it would not provide enough addresses for volumes (maybe trillions or more) of things in SCC. IPv6 can provide enough addresses for IoT [23] by introducing 6LoWPAN to bridge the scarce capabilities of constrained nodes[24],[25].

With the support of IPv6/6LoWPAN, all smart things can be connected to the current Internet. These smart devices can exchange information each other and generate web contents automatically, then Web of Things is formed. By which, users can access any devices connected to the Internet.

V. Big Data Analytics

As discussed above, big sensing data would be generated in a smart and connected community. Data technologies are the key for implementing IoT in smart and connected communities. These technologies including data storage, data organization and integration, data analysis (information extraction from data), and visualization and representation.

A. Emerging Data Storage Technologies

Magnetic recording has been the storage industry standard for decades. However, new emerging technologies such as Shingled Magnetic Recording (SMR), bit-patterned media recording (BPMR) and non-volatile memories (NVM) are introducing new feasible points for faster and higher-density storage. These new technologies also introduce new challenges. Novel physical constraints open up a fertile area for coding and signal processing research. They introduce 'non-symmetric ways' of writing symbols (e.g. a 0 might be more reliable than a 1) which require new code constructions[26].

Triple replication is the usual way that redundancy is introduced in large-scale distributed file systems (like Hadoop, GFS and Microsoft Azure). However, as data is growing faster than infrastructure, the 3x factor becomes a significant bottleneck for data center costs. For this reason distributed storage systems are deploying erasure coding techniques to provide high reliability with lower storage overheads. For these distributed environments, new code designs are needed since data blocks are distributed over a network of unreliable nodes. Microsoft designed and deployed a new 'Local storage code' in windows azure and reported savings of 100s of millions: http://research.microsoft.com/en-us/um/people/chengh/.

B. Emerging data technologies for organization and integration

Due to diversity and complexity, how to organize the sensing data has been always a primary challenge for data scientists [27][28]. Many different data models have been developed to organize data in the past decades. The development of the data models can be divided into three phases. Earlier data models include network model, relational model, entity set model and Entity-Relationship (ER) model. Network model provides a separating entities and relationships with more natural view of data, while it is difficult to achieve data independence [29]. Up to now, the relational database systems are the most widely-used in industries for its easy-to-use, though semantic factors of the data can't be reflected perfectly [29]. In the time of Internet since 1990s,semantic technologies like XML, RDF, and Semantic web came into being [1]. The main characteristic for these technologies is to represent all elements by adding some marked label to annotate corresponding meaning [30] to overcome the semantic-lacking limitation of traditional data models[31]. Volumes of diverse data are flooding in at an unimaginable rate, especially no structured contents with the development of various IoT technologies. The primary challenge for this is to find reasonable organizing models for these big data. Obviously, the traditional relational model is far from competent. Several No-sql models, such as Key-value model, Document stores model, Column Family Stores, and graph databases, have been proposed to modeling the big data. However, raw big sensing data stored in no-sql database are messily scattered and can't be used directly for two reasons. First of all, for most of them, data cannot be interpreted by the model itself, and additional features have to be handled in the application logic. Secondly, overwhelming majority of the big data are few of value while only a drop in the bucket is valuable[17].

The relations among data from different sensors are complex. Data integration is also a challenge during analysis. The data is to record and reflect the status of the physical world and its changes in cyber world in an accurate and reasonable way. As discussed above most of sensing data is meaningless. A basic question for data might be: why and how the interesting data generate? Go back to physical world: for some objects, interesting data generate only when there are some events occur. In cyber world, while data comes, the most important is to explain what the data means,i.e., what (events) happen in physical world. Therefore, the primary idea for a reasonable model is "Object-cored organizing and managing data, event-based explaining data"[18]. Such a model consists of two layers: the object layer and the event layer. The object layer would adopt an extended model of semantic link network to organize and manage the data with an object oriented way where each object could be viewed as a node and semantic relations between objects could be viewed directed links with a semantic annotation in the network. The event layer also adopts the extended model of semantic link network to organize and to manage the event information where each

[1] http://www.w3.org/

event is a semantic node and semantic relations between events can be regarded as semantic links correspondingly[18].

Each layer has a knowledge base (reasoning rule set) respectively for the purpose of finding implicit and potential and useful information by executing semantic reasoning. There are two active features for the proposed model: 1) the well-defined event schema in the event layer can be used to generate new events from the data in object layer actively, and 2) the reasoning rules stored in the knowledge bases can be used to seek out the useful and potential information like implicit relations between objects or events automatically and actively[18].

Obviously, it is convenient for information extraction and knowledge management if adopting such a two-layer model.

C. Information Extracting from big sensing data

Driven by engineering applications in which the interesting signals, data, knowledge, and information lie on low-dimensional manifolds, there is a clear need for research that extends compressed sensing, sparse coding and dictionary learning from compressed linear models to compressed nonlinear models; from signal compression, to signal classification/interpretation; from unstructured data to structured/semantic data; from Euclidean data to manifold-valued data; and from static data to dynamic data. How to extract useful events and their relations is the key further data analysis. Sun et al propose a framework to build an event-linked network from raw data [32].

D. Power issues and Green big data processing

Data centers cost hundreds of millions per year and consume more than 61 billion kilowatt-hours, 1.5 percent of the country's entire energy consumption. Increasing the efficiency of these facilities even by a small amount can lead to significant economic and environmental benefits. Intelligent algorithms to optimize energy consumption like heat monitoring, adaptively spinning down disks, elastic resource allocation etc are interesting to investigate[26].

VI. Case Study: TreSight

This section presents TreSight, a case study of IoT and big data analytics for smart tourism and sustainable cultural heritage in the city of Trento, Italy.

Trento is a medium-size Italian town of approximately 116,000 inhabitants located in Trentino-Alto Adige/Sdtirol, among the valleys leading from the Brenner Pass to the Dolomites, Garda Lake, Verona and Venice. Trento is a lively, cosmopolitan city, with highly developed and organized modern social services, committed to combine smart development and innovation with the typical charm of an alpine town with valuable historical and cultural heritage. Trento is often ranked in the very first position among Italian cities for quality of life, standard of living, and business and job opportunities.

We envision that personal sensors, open data, and participatory sensing enhance the services in the area of tourism and cultural heritage with a Context-Aware Recommendation System. The aim of TreSight is to build a context-aware recommendation system for tourism based on FI-WARE technology. This project will determinate the required data sources for offering a context-aware and knowledge-driven solution, in order to provide personalized recommendations. For this purpose, it will be used the data from OpenData Trentino regarding points of interest, weather, recommended typical restaurants, etc., and it will be extended with additional data collected through CrowdSensing with a wearable bracelet, in order to provide a fine grain level of details regarding weather, activity levels, and follow-up of the tourists activities.

Further, TreSight will analyze the potential for Big Data analytics in three Tre levels:

- insight: to understand deeply the data itself (e.g. trends and statistics)
- outsight: for its understanding in social and external aspects (e.g. events and situations correlations, such as weather influence)
- foresight: for predictions and prevention (e.g. expected visits for specific places, and the expected crowd areas)

Similar to Waze, acquired by Google, which offers real-time traffic based on CrowdSensing, TreSight looks for integrating CrowdSensing with existing data repositories, via an Open-Data approach, face to enhance/develop services with the new data sources, and extend services from cities to regions. In this way, TreSight offers advantage over traditional solutions based on infrastructure deployment, which are cost prohibitive for the majority of the cities, and consequently limited to specific areas.

The target users are cities that want to offer innovative services for citizens and visitors in a cost effective way such as cultural heritage, tourism-related companies that want to promote themselves (hotels, museums, bars, restaurants, etc.) adding their advertisements, promotion codes, coupons etc. in the mobile app that will be offered to the users for the Context-Aware Recommendation System. Examples of users are the cities that want to offer an enhanced and more innovative solution to the existing Guest or Tourist Card, e.g, Trentino Guest Card (http://www.visittrentino.it/en/trentinoguestcard), or other similar cards in Berlin, Munich, Barcelona and the top cities/regions around the world.

This new wearable bracelet will provide additional values that a Guest Card since its capabilities to crowd-sense, interact with the mobile phone, and interact with the Points of Internet, in order to provide to the system the required data to make it context-aware. The additional cost from a simple Guest Card to a Smart Wearable Bracelet are motivated by the additional functionalities, the gathering of the data, and the active involvement of the tourist, in order to make it more effective.

In addition, this kind of solutions can be partially funded by the Tourism Department of the city, but also receive sponsorship and support from the restaurants, pubs, bars, theme parks, museums, and other relevant places that have an interest to be highlighted in the applications with the provisioning of advertising, coupons, promotions, and premium content. The end-users of the solution are mainly citizens and visitors, who will be benefitted of the new services thanks to the Open

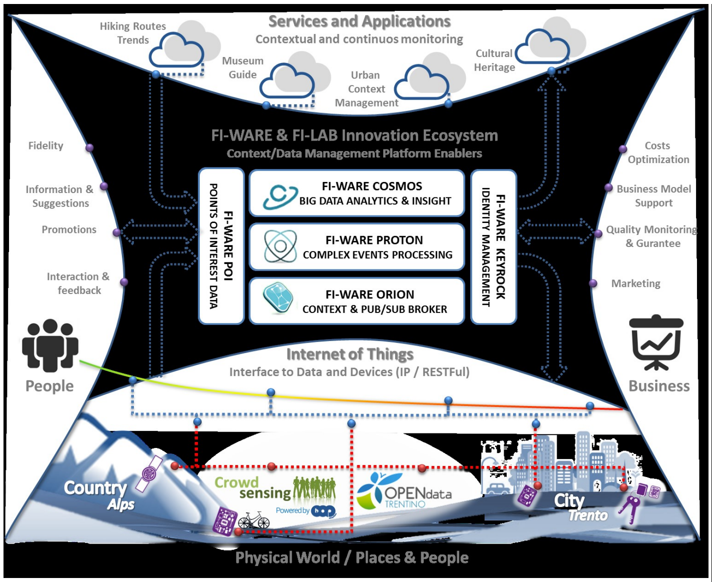

Fig. 3. *The Conceptual Architecture of TreSight.*

Data and the CrowdSensing. In addition, industries and public bodies will be also benefitted, since its availability as Open Data.

The conceptual architecture is shown in Fig.3.

A. Physical Deployment

The solution requires the deployment of a hotspot for each one of the relevant places that want to be considered a Point of Interest. The hotspot is required to:

- Gather the data about how many tourists have attended
- Update the data repository for the tourist indicating that he has visited this place face to take it into account for future recommendations and promotion
- The hotspots will collect the sensed data about humidity, temperature, noise, etc.
- They are a medium to provide additional information and content to the visitors through Bluetooth Smart
- They could be interconnectable with the system in the restaurant / museums to collect additional information about real-time availability, reservations, etc. Additionally, every visitor should use a bracelet to be able to be benefited of the promotions in every place, and to provide their context details in order to obtain personalized recommendations based on the places that have already attended and the weather conditions.

Finally, a mobile app will be usable by the visitors to interact with the bracelet, obtain the recommendations, get promotions (discounts, offers, and coupons from the promoted places and sponsors), and the most important to obtain more details about the points of interest (pictures, comments, statistics, open hours, current status information such as availability etc.). In the future, the mobile app could be also enabled with social capabilities such as discover friends in the city, interconnection with social networks, etc.

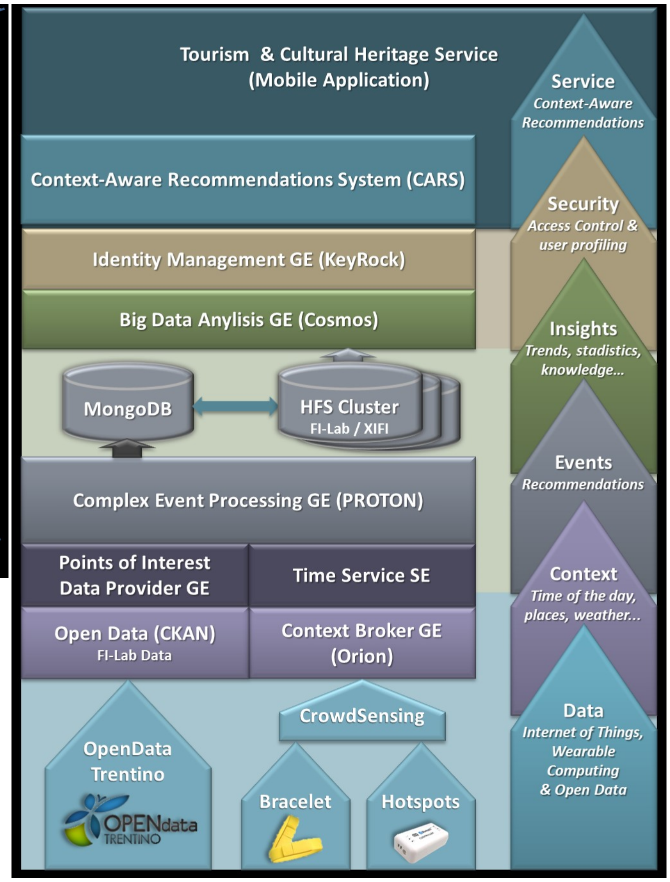

Fig. 4. *The Backend Architecture of TreSight.*

B. Backend Architecture

The backend architecture of TreSight is shown in Fig. 4.

TreSight will manage static and dynamic data, for this purpose the proposed architecture will make an optimal usage of different Generic Enablers.

1) Static Data: The static data is coming from OpenData Trentino based on CKAN (accessible via FI-LAB). This Open Data is offering the required static data source regarding relevant Points of Interest (http://dati.trentino.it/dataset/poi-trento), typical restaurants from Trentino (http://dati.trentino.it/dataset/osterie-tipiche-trentine) etc. This data will be integrated into the Points of Interest Data Provider Generic Enabler. This enabler supports tourist attractions / services, photos, videos, 3D content, special location data of specific business (in order to be able to integrate also advertising of partners or collaborators), and any other imaginary items. Thereby, it will be able to offer a valuable source of data to the tourists.

2) Dynamic Data: The dynamic data will come from two sources:

- OpenData Trentino with real-time monitoring of weather stations (http://dati.trentino.it/dataset/dati-recenti-delle-stazioni-meteo/resource/d7cdd2f4-5115-4e6d-a80c-2fdc16c4eb39).
- Crowd-sensing with information from the wearable bracelets and the deployed hotspots in the points of

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interest.

  – Wearable bracelets will crowd-sense the activity, environmental conditions (temperature / humidity), success rate (number of tourists that have attended based on the tracking of the bracelet), and other information coming from the wearable bracelet.
  – Hotspots will provide information about availability in the places, crowd-level (how many people is around), and also opening and closing hours (detecting when a hotspot is on or off).

The dynamic data will be integrated with Orion Context Broker Generic Enabler, since it supports RESTFul Web Interface (HTTP or CoAP) as our sensors. In fact, HOP Ubiquitous has contributed to the support of CoAP protocol as one of the protocols supported by Orion Context Broker Generic Enabler. Orion is a context broker for Publish/Subscribe communication that will optimize our sensors communication performance and integrate them into the FI-WARE context and data management platform. The dynamic data will be tagged with a timestamp, this timestamp will be calculated with the Time Service Specific Enabler from FI-STAR. This Specific Enabler provides a Network Time Protocol that satisfies the requirements for real-time solutions. This timestamp will be added since the dynamic data will have a limited lifetime, and it depends on the specific moment that it is captured. For example, weather status is only relevant for a specific period of time.

All the dynamic data will be converted into relevant events with the PROTON Complex Event Processing Generic Enabler. In details, it will detect events such as the weather evolution, the opening and closing times of a Point of Interest, and the activity evolution.

Additionally, COSMOS Big Data Generic Enabler will be used to integrate Hadoop in order to process all the static data, dynamic data, and events, in order to provide advanced learning capabilities, in terms of trends analysis, and knowledge extraction. As a personal source of data, and for security issues, the Identity Management KeyRock Generic Enabler will be integrated to allow the users to create an user/password that they could use to log-in from the mobile phone application and web platform. This Identity Management will offer OAuth 2.0 capabilities in order to make the credentials reusable for other systems in the City/Region. In addition, to make easier the usage and creation of credentials, we will enable/integrate other OAuth 2.0 severs such as Facebook and/or Linkedin. Therefore, users in the solution can be created from zero, or using existing accounts in the most popular social platforms. At the end, the city will keep a record of the users/visitors in the system. The integration with the other social platforms will make easier the gathering of other details such as age, gender, nationality, etc. Remark, that this additional personal-related data will be also a source of information for the system, since different recommendations will be considered for different age-ranges, genders, etc.

Finally, all the events are processed with PROTON, the personal data (age, gender, etc.) from KeyRock, the crowd-sensed data from the bracelet (places already visited, weather, success rates, noise levels, etc.) and integrated with Orion, the data from the Open Data Trentino (recommended places, points of interest, museums, etc.), and any additional data integrated through the mobile application that the users will use to get the recommendations and provide their interests will be used to build the Context-Aware Recommendation Systems.

VII. Challenges of Applying IoT and Big Data Analytics in Smart and Connected Communities

There are several challenges in applying IoT to smart towns for culture preservation and revitalization, such as reasonable data model, security and privacy problems, technologies for featured culture and heritage protection, Robustness of applications, and etc.

- Reasonable data organization model for SCC. Traditional data models can't meet the requirements of the next trend of implementation of SCC. The requirements of a well-defined data model for smart SCC involves in several aspects. First of all, semantic factors is the key for fully intelligentization in smart towns which is the next step for the development of IoT, also known as the Semantic Web of Things [33]. A semantic data model, which enables to understand and explain the data captured by the sensing devices in smart towns, is required for implementation of intelligent towns. Semantic interfaces are the most important technologies for realizing the interconnection and interactive communication among smart objects. Active reasoning with the support of enriched semantics is an essential module for the integration of knowledge and intelligence. A well-defined semantic data model is the primary foundation to support these semantic technologies. Secondly, enabling to integrate heterogeneous data. The massive volume and heterogeneity are the primary features of the data in smart towns which is determined by the trillions and the varieties of things. It is a grand challenge to organize and manage these data in an efficient and effective way, especially to execute queries and operations in such a tanglesome context. A well-build data model is required to provide a quick and flexible solution to seek out the destinations relevant to the problems.
  Architectures are really needed for SCC which can provide or support integration of personal communications, sensing, and computing for dense, highly mobile devices and data sources.
- Technology challenges for protecting featured cultures and heritages. Many cultures and customs derived from many ancient traditions, and deeply rooted in the hearts of local residents. These cultures are hard to monitored by sensing devices. Audio and video recordings can only capture the external form of these activities, it is difficult to get the essence.
- Security and Privacy. For individuals, SCC will provide many conveniences and useful services. Meanwhile, Security attacks and privacy violation are problematic for SCC. Due to minimal capacity things, accessibility to sensors/actuators/objects, and systems openness, security

would be one of the most important challenge for SCC. The ubiquity of services including mobile services would lead to privacy violations for individuals. To solve the privacy problem caused by smart applications in SCC, privacy rules for each services(applications) should be embedded. Furthermore, SCC paradigm must be able to express users requests for data access and the policies such that the requests can be evaluated against the policies in order to decide if they should be granted or denied[**?**].

- Robustness of applications in SCC. Variety of services would be based on the collaborations of number of devices for sensing, actuation, and connecting network of things. It is a big challenge to have all the involved devices to work together due to different locations, synchronize problems, capture neighbor devices when cooperating, and etc., especially, over time these conditions can deteriorate[**?**].

VIII. Conclusion

This article proposes the concept of ”smart and connected communities (SCC)”, which is a unified framework integrating smart cities and beyond. Different from big cities, small communities call for culture preservation in addition to revitalization. IoT technologies could potentially serve this need. This article develops an IoT architecture, and choose best IoT enabling technologies, and IoT services, applications, and standards, towards this goal. The purpose of this article is to introduce a novel concept called ”SCC” whose vision is to improve livability, preservation, revitalization, and sustainability, of a small town, different from so-called smart cities. In this article, we shed light on the opportunities and challenges of applying IoT and big data analytics to culture preservation and revitalization of SCC. We expect that the intelligent use of IoT and big data analytics could breathe new life into traditional, close-knit culture of SCC. As a case study, we present TreSight which integrates IoT and big data analytics for smart tourism and sustainable cultural heritage in the city of Trento, Italy.

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