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Internet of Things for Cultural Heritage of Smart Cities and Smart Regions

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Abstract—Different from big cities, small towns 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. In this article, we focus on the opportunities and challenges of applying IoT to culture preservation and revitalization of smart towns. We expect that the intelligent use of IoT could breathe new life into traditional, close-knit culture of small towns.

Index Terms—Internet of Things, Smart Towns, Culture Preservation, Cultural Heritage.

I. Introduction: Smart Towns vs Big 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 [2]. 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 [3]. 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 [4]. 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.

One important application of IoT is smart cities [5], 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 [6]. The vision of IoT for smart cities is to improve the 'livability' of cities[7]. However, 46 percent of the world's population lives in rural areas, rather than urban areas [8]. In the United States, almost 53 million people live in small towns with populations of fewer than 25,000 [9]. 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 towns are historic, even ancient. 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.

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 [10].

Therefore the IoT architecture, protocols and technologies for smart cities could not be applied directly to towns. 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 [11]. 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) [11]. The application of IoT technologies for a smart town is to remember the past, live in the present,

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and plan for the future, of a town. The purpose of this paper is to identify the opportunities and challenges when the IoT technologies are applied to small towns. This paper is organized as follows. Section II presents a vision of smart town and highlights the differences of smart towns from smart cities: preservation, revitalization, and sustainability. Section III and Section IV presents the opportunities brought by IoT for s- mart towns, including IoT architectures, enabling technologies, services, applications, and standards, and then challenges of applying IoT to smart towns. Section V concludes this paper.

II. Concepts

The concept of ”Smart Town” was proposed in [11] 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 ”Smart Town” is to improve livability, preservation, revitalization, and sustainability, of a town [11], 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 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) [11] . 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.

A. Livability

The vision of IoT for smart cities is to improve the ’livability’ [7], which is among four elements of the vision of IoT for smart towns. 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 her- itage 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. For example, Dong’e town is an ancient town full of cultural heritage and natural heritage located in Shandong Province, China. One of its tangible cultural heritage sites is Yongji bridge which was built in 1500. Its intangible heritage is ejiao, also called Donkey-hide gelatin or ass-hide glue, for which Dong’e town is nationally named as ”Home of Donkey-hide Gelatin in China” and is one of the three famous Chinese traditional specialty towns with Maotai Town and Jingde Town.Also Dong’e town was included on the first list of Chinese intangible cultural heritage. Its natural heritage has the tomb of Cao Zhi, a son of Cao Cao, who was a well- known poet of the Wei state (A.D. 220-265) during the Three Kingdoms Period. He was buried at the west foot of the Yushan Mountain in Dong’e County of Shandong Province. The tomb was first built in the seventh year of the Taihe Period of the Wei Kingdom (233 A.D.). The tomb of bricks and stones was nestling by the mountain, occupying an area of about 1200 mu. There are altogether 132 pieces of burial articles excavated from the tomb, including stone gui (an elongated pointed tablet of jade held in the hands by ancient rulers on ceremonial occasions), stone bi (a round flat piece of jade with a hole in it), green jade huang (a jade pendant of semi-circular shape), agate ball, mica sheet as well as pottery ware etc. [13]UNESCO, Protecting Our Heritage and Fos- tering Creativity, http://en.unesco.org/themes/protecting-our-heritage-and-fostering-creativity

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. However, 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 change [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 sustainabil- ity challenges, such as water management, improved urban planning, supporting biodiversity, and food production [16].

Fig. 1. The Vision of Smart Town

III. IoT Function Architecture and Enabling Technologies for Smart Towns

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.

A. IoT Function Architecture for 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 Internet of Things for smart towns involves in 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 infor- mation 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 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 for this layer are listed as follows.
  - Storing the massive, trivial, and heterogeneous data 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.
  - 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.

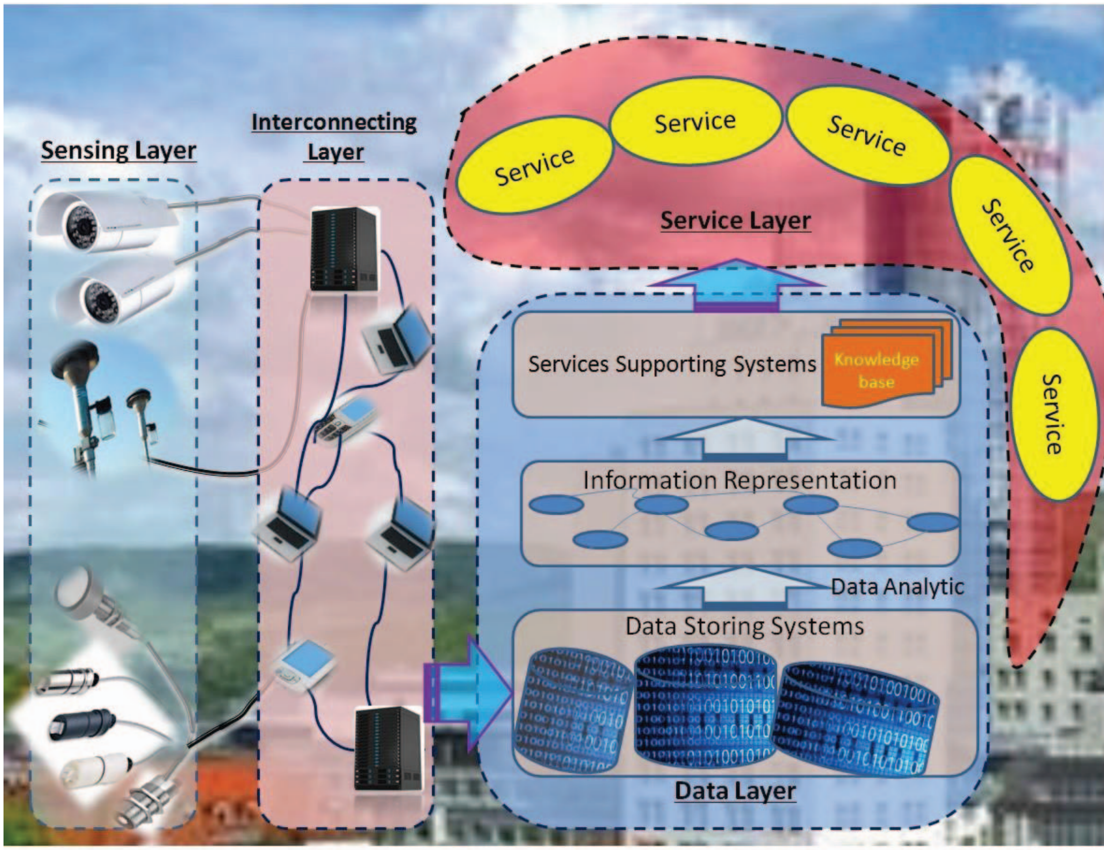

Fig. 2. Function Architecture of Internet of Things for Smart Towns

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.

– 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. 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. In addition to replacing the outdated knowledge with the new ones according to the evolution of the Internet of Things, 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.
  – Smart infrastructure services include Smart Parking, structural health, Noise Urban Maps, Smartphone Detection, Eletromagnetic Field Levels, Traffic Congestion, Smart Lighting, Waste Management, Smart Roads.
  – Smart Environment services include Forest Fire Detection, Air Pollution, Snow Level Monitoring, Landslide and Avalanche Prevention, Earthquake Early Detection.
  – Smart Water Services include Potable water monitoring,Chemical leakage detection in rivers, Swimming pool remote measurement,Pollution levels in the sea, Water Leakages, River Floods.
  – Smart Metering Services include smart grid, Tank level, Photovoltaic Installations,Water Flow,Silos S-

tock Calculation.
– Security & Emergencies service include Perimeter Access Control,Liquid Presence,Radiation Levels,Explosive and Hazardous Gases.
– Retail Services include Supply Chain Control,NFC Payment, Intelligent Shopping Applications,Smart Product Management.
– Logistics services include Quality of Shipment Conditions, Item Location, Storage Incompatibility Detection, Fleet Tracking.
– Industrial Control services include M2M Applications, Indoor Air Quality, Temperature Monitoring, Ozone Presence, Indoor Location,Vehicle Autodiagnosis.
– Smart Agriculture services include Wine Quality Enhancing, Green Houses, Golf Courses, Meteorological Station Network, Compost.
– Smart Animal Farming services include Hydroponics, Offspring Care, Animal Tracking, Toxic Gas Levels.
– Domotic & Home Automation services include Energy and Water Use, Remote Control Appliances, Intrusion Detection Systems, Art and Goods Preservation.
– eHealth services include Fall Detection, Medical Fridges, Sportsmen Care, Patients Surveillance, Ultraviolet Radiation.

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*ŭ* 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.

B. *Smart town IoT Enabling Technologies*

According to the architecture of the IoT for smart towns, 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.

1) Sensing Technologies for Smart town: 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.

2) Internet Technologies for Smart town: 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 IoT of smart towns, each thing 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 smart towns. IPv6 can provide enough addresses for IoT [17] by introducing 6LoWPAN to bridge the scarce capabilities of constrained nodes[18],[19].

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.

3) Emerging Data Technologies for Smart town: As discussed above, big sensing data would be generated in a smart town. Data technologies are the key for implementing IoT in smart towns. These technologies including data storage, data organization and integration, data analysis (information extraction from data), and visualization and representation.

- 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[20].

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/.

- 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 [21][22]. 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 [23]. 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 [23]. 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 [24] to overcome the semantic-lacking limitation of traditional data models[25]. 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[26].

  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"[27]. 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 event is a semantic node and semantic relations between events can be regarded as semantic links correspondingly[27].

  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[27].

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

- 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 [28].
- 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

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

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[20].

IV. Challenges of Applying IoT to Culture Preservation and Revitalization of Smart Towns

Challenges of applying IoT to culture preservation and revitalization of smart towns involves in many aspects, 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 smart towns. Traditional data models can't meet the requirements of the next trend of implementation of smart towns. The requirements of a well-defined data model for smart towns 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 [29]. 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 smart towns 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, the smart town will provide many conveniences and useful services. Meanwhile, Security attacks and privacy violation are problematic for the smart town. Due to minimal capacity things, accessibility to sensors/actuators/objects, and systems openness, security would be one of the most important challenge for smart town. The ubiquity of services including mobile services would lead to privacy violations for individuals. To solve the privacy problem caused by smart applications in smart towns, privacy rules for each services(applications) should be embedded. Furthermore, smart town 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[2].
- Robustness of applications in smart towns. 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[2].

V. Conclusions

Different from big cities, small towns call for culture preservation in addition to revitalization. IOT could potentially serve this need. We must develop an IOT architecture, and choose best IOT enabling technologies, and IoT services, applications, and standards, towards this goal. In this article, we shed light on the opportunities and challenges of applying IOT to culture preservation and revitalization of smart towns. We expect that the intelligent use of IOT could breathe new life into traditional, close-knit culture of small towns.

References

[1] I. T. Union). (2012) Overview of the internet of things. [Online]. Available: https://www.itu.int/rec/T-REC-Y.2060-201206-I

[2] J. A. Stankovic, "Research directions for the internet of things," 2014.

[3] W. Zhao, "Internet of things - what and how," *IEEE Real-Time Systems Symposium*, 2012.

[4] N. N. S. Foundation). (2014) Cyber-physical systems (cps). [Online]. Available: http://www.nsf.gov/funding/pgm_summ.jsp pims_id=503286

[5] A. Zanella, N. Bui, A. P. Castellani, L. Vangelista, and M. Zorzi, "Internet of things for smart cities," *IEEE Internet of Things Journal*, 2014.

[6] R. Y. Clarke, "Smart cities and the internet of everything: The foundation for delivering next-generation citizen services," *Alexandria, VA, Tech. Rep*, 2013.

[7] S.-W. A. L. Shane Mitchell, Nicola Villa Martin. (2013) The internet of everything for cities: Connecting people, process, data, and things to improve the livability of cities and communities. [Online]. Available: http://www.cisco.com/web/about/ac79/docs/ps/motm/IoE-Smart-City_PoV.pdf

[8] R. Miles, "United nations department of economic and social affairs," 2009.

[9] R. Wuthnow, *Small-town America: Finding Community, Shaping the Future*. Princeton University Press, 2013.

[10] B. Herman. (2012) What are some of the challenges facing rural and small town america? (webinar). [Online]. Available: http://www.epa.gov/smartgrowth/pdf/webinar2/ref_Herman_081612.pdf

[11] H. Song, "Internet of things for rural and small town america(invited talk)," in *6th Annual Create West Virginia Training and Education Conference*, October 2013, pp. 1–6.

[12] U. U. D. of Transportation). (2013) Livability 101. [Online]. Available: http://www.dot.gov/livability/101

[13] UNESCO. (2014) Protecting our heritage and fostering creativity. [Online]. Available: http://en.unesco.org/themes/protecting-our-heritage-and-fostering-creativity

[14] N. D. Milder and A. Dane, "Revitalizing small towns: Resolving downtown challenges," *The Economic Development Journal*, 2013.

[15] U. N. G. Assembly, "Report of the world commission on environment and development: Our common future," , Tech. Rep., 1987.
[16] L. I. Millett and D. L. Estrin, *Computing Research for Sustainability*. Washington D.C.: The National Academies Press, 2012.
[17] S. E. Deering, "Internet protocol, version 6 (ipv6) specification," 1998.
[18] G. Montenegro, N. Kushalnagar, J. Hui, and D. Culler, "Transmission of ipv6 packets over ieee 802.15. 4 networks," *Internet proposed standard RFC*, vol. 4944, 2007.
[19] J. Hui and P. Thubert, "Compression format for ipv6 datagrams over ieee 802.15. 4-based networks," 2011.
[20] N. N. S. Foundation). (2014) Nsf workshop on big data: From signal processing to systems engineering. [Online]. Available: http://www.dtc.umn.edu/resources/bd_finalreport.pdf
[21] M. Balazinska, A. Deshpande, M. J. Franklin, P. B. Gibbons, J. Gray, M. Hansen, M. Liebhold, S. Nath, A. Szalay, and V. Tao, "Data management in the worldwide sensor web," *IEEE Pervasive Computing*, vol. 6, no. 2, pp. 30–40, 2007.
[22] J. Cooper, A. James *et al.*, "Challenges for database management in the internet of things," *IETE Technical Review*, vol. 26, no. 5, p. 320, 2009.
[23] E. F. Codd, "A relational model of data for large shared data banks," *Communications of the ACM*, vol. 13, no. 6, pp. 377–387, 1970.
[24] T. Berners-Lee, W. Hall, J. A. Hendler, K. O'Hara, N. Shadbolt, and D. J. Weitzner, "A framework for web science," *Foundations and trends in Web Science*, vol. 1, no. 1, pp. 1–130, 2006.
[25] H. A. Schmid and J. R. Swenson, "On the semantics of the relational data model," in *Proceedings of the 1975 ACM SIGMOD international conference on Management of data*. ACM, 1975, pp. 211–223.
[26] Y. Sun, H. Yan, J. Zhang, Y. Xia, S. Wang, R. Bie, and Y. Tian, "Organizing and querying the big sensing data with event-linked network in the internet of things," *International Journal of Distributed Sensor Networks*, vol. 2014, 2014.
[27] Y. Sun and A. J. Jara, "An extensible and active semantic model of information organizing for the internet of things," *Personal and Ubiquitous Computing*, pp. 1–13.
[28] Y. Sun, H. Yan, C. Lu, R. Bie, and Z. Zhou, "Constructing the web of events from raw data in the web of things," *Mobile Information Systems*, vol. 10, no. 1, pp. 105–125, 2014.
[29] A. J. Jara, A. C. Olivieri, Y. Bocchi, M. Jung, W. Kastner, and A. F. Skarmeta, "Semantic web of things: an analysis of the application semantics for the iot moving towards the iot convergence," *International Journal of Web and Grid Services*, vol. 10, no. 2, pp. 244–272, 2014.