Iot-based Smart Cities: a Survey

H. Arasteh, V. Hosseinnezhad
Dept. Electrical Engineering,
Shahid Beheshti University, A.C.,
Tehran, Iran
h_arasteh@sbu.ac.ir,
v_hosseinnezhad@sbu.ac.ir

V. Loia, A. Tommasetti, O. Troisi
Dept. Management & Innovation
Systems, University of Salerno,
Salerno, Italy
loia@unisa.it, tommasetti@unisa.it,
otroisi@unisa.it

M. Shafie-khah, P. Siano
Dept. Industrial Engineering
University of Salerno, Salerno, Italy
miadreza@ubi.pt, psiano@unisa.it

***Abstract*— Due to the growing developments in advanced metering and digital technologies, smart cities have been equipped with different electronic devices on the basis of Internet of Things (IoT), therefore becoming smarter than before. The aim of this article is that of providing a comprehensive review on the concepts of smart cities and on their motivations and applications. Moreover, this survey describes the IoT technologies for smart cities and the main components and features of a smart city. Furthermore, practical experiences over the world and the main challenges are explained.**

Keywords*— *Internet of Things (IoT), Smart City, Smart Grids, Smart Buildings, Demand Response, Smart Governance.

I. INTRODUCTION

A. Concepts

Due to the rapid growth of the population density in urban cities, infrastructure and services are required to provide the necessities of the city residents. On this basis, there is a significant increase for digital devices, e.g. sensors, actuators, and smartphones that drive to huge business potentials for the IoT, since all devices can interconnect and communicate with each other on the Internet [1].

The IoT prototype is subject to smart and self-configuring objects that are connected to each other through a global network infrastructure. IoT is mostly considered as real objects, broadly scattered, with low storage capability and processing capacity, with the target of improving reliability, performance and security of the smart city and its infrastructures [2]. With this knowledge, in this article, a review of the IoT-based smart city is carried out.

B. Motivations

Smart cities have become smarter than before thanks to the recent developments of digital technologies. A smart city is equipped with different electronic elements employed by several applications, like street cameras for observation systems, sensors for transportation systems, etc. In addition, this can spread the usage of individual mobile devices. Therefore, by considering the heterogeneous environment, different terms, such as features of objects, contributors, motivations and security rules should be investigated [3]. Reference [4] introduced some of the main aspects of a smart city in 2020. These aspects are shown in Fig. 1.

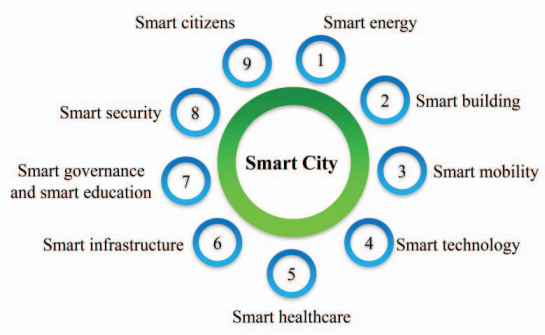

Fig. 1. The main aspects of a smart city

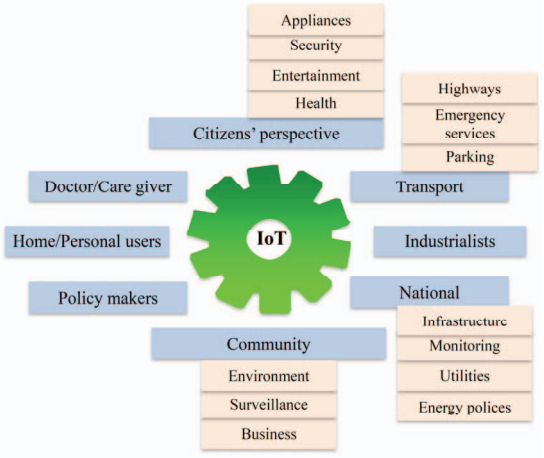

Fig. 2. IoT-based interconnections

In the IoT context, devices can be integrated based on the geographic location and evaluated by using an analyzing system. Sensor services for the collection of particular data can be used with several occurring projects concerning the monitoring of cyclists, vehicles, public parking lots, etc. There are many service domain applications that use an IoT infrastructure in order to facilitate operations in air and noise pollution, the mobility of vehicles and surveillance systems.

The revolution of the Internet provides an infrastructure in which many people are able to interconnect to each other. The next revolution of the Internet will make it possible to provide suitable interconnections among the objects. In 2011, the number of objects that are interconnected together was much more than the number of people [5]. Fig. 2 shows the

978-1-5090-2320-2/16/$31.00 ©2016 IEEE

interconnection among the various objects based on the IoT [5]. Accordingly, on one hand, IoT will affect the various aspects of the smart city citizens' life like health, security, and transportation. On the other hand, it can play an important role at the national level regarding to the policy decisions (like energy saving, pollution decrement, etc.), remote monitoring, and required infrastructure. On this basis, the IoT will help to provide more efficient, economic and secure operation of the system based on different aspects, such as energy saving policies, economic considerations, reliability levels, etc.

II. IOT TECHNOLOGIES FOR SMART CITIES

The IoT is a broadband network that uses standard communication protocols [6, 7] while its convergence point is the Internet. The main concept of the IoT is the universal presence of objects that can be measured, inferred, understood and that can change the environment. On this basis, IoT is enabled by the developments of various objects as well as communication technologies. Involved things in the IoT consist of smart devices including mobile phones and other objects like foodstuff, appliance, landmark, monument, work of art [9, 10] that can cooperate together to provide a common target. The impact of the IoT on the life of users can be considered as its key feature [4]. Some of the IoT-related technologies are discussed in the following.

A. Radio-Frequency Identification (RFID)

These systems consisting of readers and tags are playing a key role in the context of the IoT. By applying these technologies to any involved object, it is possible to carry out their automatic identification and assign a unique digital identity to each object, in order to be incorporated in the network and related to the digital information and service [8].

B. Wireless sensor network (WSN)

WSNs can provide different suitable data and also may be used in many cases such as healthcare, government and environmental services and seismic sensing [10]. Furthermore, WSNs could be integrated with RFID systems to gain some goals like obtaining information regarding the position, movement, temperature, etc.

C. Addressing

As well as the Internet can enable a remarkable interconnection of people, the existing trend in the IoT can similarly provide an interconnection of objects and things, in order to establish smart environments [5]. To this end, the capability of uniquely identifying objects is crucial for favorable outcomes of the IoT. This is due to the fact that uniquely addressing the large-scale combination of objects is vital for controlling them via the Internet. In addition to the mentioned uniqueness concept, reliability, scalability as well as persistence denote the key requirements to develop a unique addressing scheme [5].

D. Middleware

As a result of some issues related to the heterogeneity of contributing things, to the restricted storage and process capability, as well as to the enormous diversity of applications, the middleware plays a critical role in the interconnection of the objects to the application layer. The key objective of the middleware is, indeed, to concisely integrate the functionalities and communication capabilities of all involved devices.

III. IOT ACTUAL APPLICATIONS FOR SMART CITIES

The IoT utilizes the Internet to incorporate heterogeneous devices with each other. In this regard and in order to facilitate the accessibility, all available devices should be connected to the Internet. In order to achieve this target, sensors can be developed at different locations for collecting and analyzing data to improve the usage [2]. Fig. 3 illustrates the main applications of the IoT for smart cities. The main aims in this area of knowledge are explained as the follows.

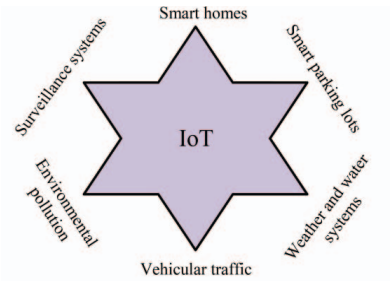

Fig. 3. The main applications of the IoT

A. Smart homes

Smart homes could be monitored by using the data that are generated by the sensors [11]. For instance, innovative demand response (DR) functions can be implemented or by monitoring the pollution, it will be possible to alert customers if the pollution exceeds its marginal limit.

B. Smart parking lots

By enabling smart parking, arrival and departure of various vehicles can be tracked for different parking lots distributed in the city [12]. Consequently, the smart parking lots should be designed in a way to consider the number of cars in each zone [13]. Moreover, new parking lots should be established where a higher number of vehicles are available [14]. Correspondingly, the data of smart parking lots can bring advantages for both vehicle owners' and merchants' daily lives in a smart city.

C. Weather and water systems

Weather and water systems can utilize some sensors to provide suitable information like temperature, rain, wind speed, and pressure and can contribute to enhance the efficiency of the smart cities [2].

D. Vehicular traffic

Vehicular traffic data are one of the most important data sources in a typical smart city in which, by using these data and applying a suitable analysis, citizens and the government will benefit greatly [12]. Citizens could be also able to use the vehicular traffic data to determine the arrival time to a destination [15].

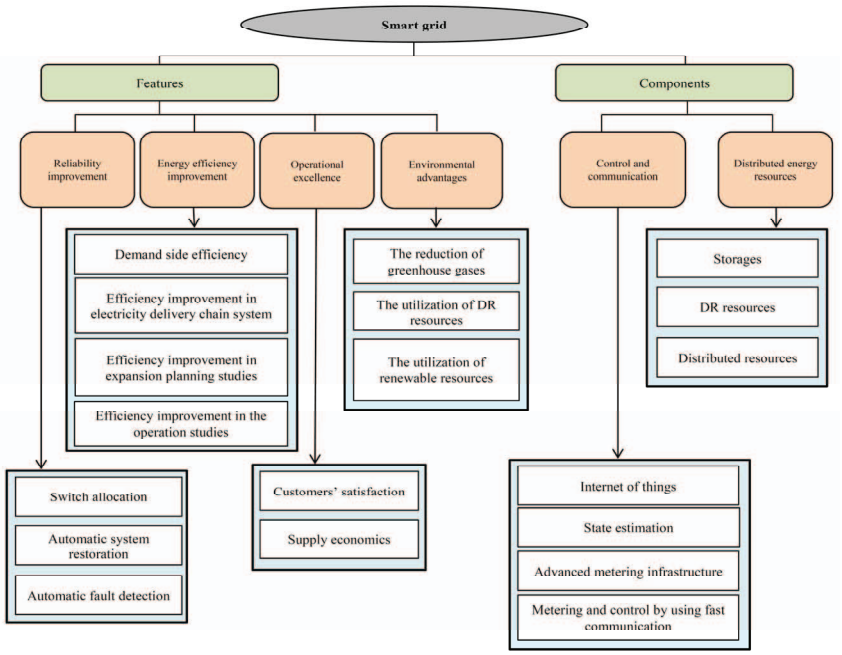

Fig. 4. The main specifications of smart grids

E. Environmental pollution

A city cannot be considered as a smart one if its citizens are unhealthy. To this end, a smart city should monitor the environmental pollution and deliver the related information to citizens, especially to those with health care conditions. Reference [1] also reported a separate module to achieve noise and environmental data.

F. Surveillance systems

In a smart city, security is the most important factor from the citizens' viewpoint. For this purpose, the whole smart city should be continuously monitored. However, analyzing the data and detecting crimes are very challenging. Reference [1] has proposed new scenarios to enhance the security of the smart city.

IV. IoT Potential Applications for Smart Cities

Fig. 4 indicates some of the future applications of the IoT for the smart cities that are discussed in this section.

A. Smart cities and communities

The implementation of the IoT can result in the generation of some services that have an interaction with the environment. Hence, it could introduce some opportunities for contextualization and geo-awareness. Furthermore, collective intelligence will improve the processes of decision making and empower the citizens [16]. In addition, a common middleware could be available for future services of the smart city by using the IoT [17]-[19]. It should be mentioned that sensor virtualization could be utilized to decrease the gap among the current technologies and the potential customers [20].

B. Smart homes

Through the IoT platform in the home, the heterogeneous devices will enable the automation of common activities. In fact, by transforming objects into information appliances that are connected to each other by using the Internet may perform services via the web interfaces. A large number of smart-home applications use sensor networks. The mentioned applications realize smart devices' connection to the Internet to observe or control them remotely [21, 22]. For example, smart lighting has been highly investigated in recent years [23, 24]. Nineteen percent of global electricity consumption is for lighting that may cause six percent of emission related to greenhouse gasses [25]. In this regard, up to forty five percent of the required energy for lighting could be saved by using the smart lighting control mechanisms [24].

C. Responsive customers

Transactive controllers and many other smart devices can be utilized to manage smart homes [26-29]. In [26] a home gateway is introduced in order to allow the home controller to cooperate with the aggregator who is responsible to collect data from many homes. Based on the signals from transactive controllers, the aggregator is able to specify the electricity purchasing prices from the electricity market and send the signals about the acceptance/rejection of bids to these devices.

The possibility for monitoring and controlling the electrical appliances can enhance the participation of the active customers in the operation of the system that is well-known as demand response. Demand side activities are reported by the International Energy Agency (IEA) to be the key option in every energy policy decision, due to the operational and economic advantages [27-31]. According to DR, electricity

consumers can adjust the electricity usage pattern with the aim of reliability enhancement or to prevent the power price spikes [32, 33].

The predictions about future electrical systems are highly concentrated on the importance of smart grids, renewable generations, pollution decrement programs, as well as enhanced DR [33]. Smart grids focused on the environmental-based programs combining different renewable generations and DR in order to provide different options for consumers and improve the usage of facilities [14, 34, 35].

D. Smart energy and smart grids

The utilization of the IoT can furnish intelligent management of energy distribution and consumption in heterogeneous circumstances. The IoT nodes have some abilities such as sensing and networking which raise the possibility of optimal scheduling of energy suppliers. This management can also be extended to emergency conditions. One of the most important results of this extension is fault location, isolating and service restoration (FLISR) [36]. Implementing this property thanks to the IoT provides an advanced tool which determines the position of the defective parts, separates them, and applies switching task to recover the largest number of healthy part of the affected energy feeder. Also, at the advanced level, this function can be developed by using self-healing methods that are able to activate the participation of the customers as well as of dispersed generation units [37]. Implementing these strategies leads to increase the reliability, power quality and profits [37]. Some of the main specifications of the smart grids are categorized in Fig. 5.

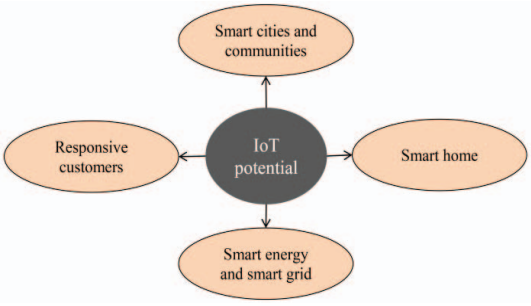

Fig. 5. IoT potentials for the smart cities

V. PRACTICAL EXPERIENCES OVER THE WORLD

Based on the US National Intelligence Council report, the IoT is one of the most effective tools on the US interests on the way to 2025 [9]. As mentioned before, the number of interconnected devices surpassed the population in 2011. This trend was significantly growing as the number of interconnected devices was about 9 billion in 2012 and they will reach 24 billion until 2020 [5]. Based on the mentioned numbers, the IoT will definitely be one of the major resources of big data in future [38]. The main policies and outcomes of smart cities are recorded in the Intelligent Community Forum awards from 1999 to 2010, for the following cities: Suwon and Seoul (South Korea), Taipei (Taiwan), Mitaka (Japan), Singapore, Waterloo and Calgary (Canada), Glasgow (Scotland), New York City and Georgia (USA), and Tehran (Iran) that were acknowledged for their attempts and achievements in establishing broadband networks and e-services supporting advance ecosystems [40-47]. Some of the experimental examples around the practical experiences of smart cities are presented in Table I.

TABLE I. POLICIES AND STRATEGIES OF CITIES RELATED TO SMART CITY

City	Experience
Amsterdam [40]	Decreasing the traffic, energy saving, and increasing the safety level
Barcelona [41-45]	Implementation of sensor technology, using the data analysis of traffic flows to design a novel bus network and the implementation of smart traffic
Stockholm [46]	Provide a universal fiber optic network across Stockholm
Santa Cruz [47]	Analyze the data of crimes to forecast the needs of police and maximize the presence of police in the required places

VI. CHALLENGES

This section deals with the typical challenges raised by the application of the IoT-based smart cities.

A. Security and privacy

When all the data are collected and analyzed in a common IoT platform, the system can be subjected to several attacks (e.g., cross-site scripting, and side-channel). Besides, such a system is exposed to important vulnerabilities. Furthermore, multi-tenancy of this system can also bring out the security issues and cause the leakage of data [2].

B. Heterogeneity

The IoT system has typically evolved with distinguished solutions in which every system component is knitted to the particular application context. Accordingly, the authorities must analyze their target scenarios, determine the required computing hardware and software and then integrate these heterogeneous subsystems. The existence of such infrastructures and the provision of a suitable collaborating scheme between them can be truly a big challenging task for the IoT system.

C. Reliability

There are some reliability issues that have arisen in the IoT-based system. For instance, because of the vehicles' mobility, the communication with them is not reliable enough. Furthermore, the presence of numerous smart devices will cause some reliability challenges in terms of their failure [48].

D. Large scale

Some specified scenarios require the interactions between large numbers of embedded devices which are possibly distributed over wide area environments. The IoT systems provide a suitable platform that can analyze and integrate data coming from different devices [2, 46-52]. However, such large scale of information requires suitable storage and computational capability collected at high-rate which makes typical challenges harder to overcome. On the other hand, the

distribution of the IoT devices can affect the monitoring tasks because these devices must handle the delay related to dynamics and connectivity.

E. Legal and social aspects

The IoT system may be service based on the user-provided information. For such cases, the service provider has to be in accordance with different local and international laws. Also, the users should have enough incentives to participate in the defined scenarios and data collection. It will be more convenient if opportunities are given to the users to select and take part in submitting data which denote a thing [52]. Reference [53] deals with the issues of systems which incorporate humans as a data resource to provide a secure interaction.

F. Big data

Considering about 50 billion devices, it is certainly necessary to pay attention to transferring, storing and recalling and also analyzing such a huge amount of data produced by them [2]. It is obvious that the IoT infrastructures will be some of the major resources of big data.

G. Sensor networks

Sensor networks can be considered as one of the most important technologies to enable the IoT [54]. This technology is able to shape the world by providing the ability of measuring, inferring, and understanding environmental indicators [5]. Recent developments and improvements in technologies have provided devices with high efficiency and low-cost to employ remote sensing applications in large-scale [55]. In addition, smartphones are associated with a diversity of sensors and, consequently, they enable a variety of mobile applications in several areas of IoT. To this end, the major challenging task is to process the large-scale data of the sensors in terms of energy and network limits and various uncertainties [56].

H. DR barriers

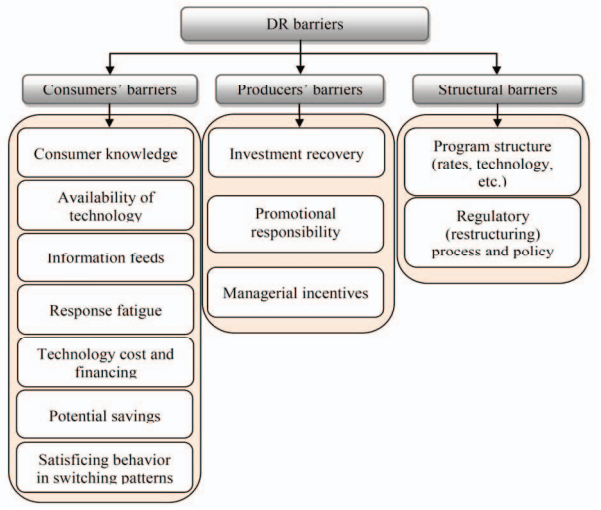

Fig. 6. DR barriers

Although the IoT can facilitate the participation of the responsive loads in the system, there are still various kinds of barriers that can limit the penetration of DR. As shown in Fig. 6, such barriers are classified into three main sets, namely; consumers' barriers, producers' barriers, and structural barriers that are completely investigated in [57].

VII. CONCLUSION REMARKS AND FUTURE TRENDS

The recent literature was reviewed to investigate variant features and characteristics of the IoT systems as well as the effective motivations of using them. Since implementation of the IoT infrastructures could enable a number of opportunities, firstly the highest research motivations are described and then some useful applications outlined. It is described how daily activities can be developed and enhanced by utilizing them. Also, the challenges which arise when implementing the IoT system were thoroughly explained. In this regard, the combination of the IoT platform with other autonomous and intelligent systems for providing smart and widespread applications is one of the most interesting future trends. Furthermore, providing a mechanism to overcome some of the essential challenges like the privacy right of the citizens is still an area of interest. The IoT with its functionality and features should, in fact, utilize intelligent systems and sensors to preserve the rights of the smart city citizens.

REFERENCES

[1] M. M. Rathore, A. Ahmad, A. Paul, and S. Rho, "Urban planning and building smart cities based on the internet of things using big data analytics", Comput. Netw., 2016, DOI: 10.1016/j.comnet.2015.12.023.

[2] A. Botta, W. de Donato, V. Persico, and A. Pescapé, "Integration of cloud computing and internet of things: a survey", Future Gener. Comput. Syst., vol. 56, pp. 684–700, 2016.

[3] D. Kyriazis, T. Varvarigou, A. Rossi, D. White, and J. Cooper, "Sustainable smart city IoT applications: heat and electricity management & Eco- conscious cruise control for public transportation," IEEE 14th International Symposium and Workshops on World of Wireless, Mobile and Multimedia Networks, pp. 1–5, 2013.

[4] "Strategic opportunity analysis of the global smart city market", http://www.egr.msu.edu/~aesc310-web/resources/SmartCities/Smart%20City%20Market%20Report%202.pdf.

[5] J. Gubbi, R. Buyya, S. Marusic, and M. Palaniswami, "Internet of Things (IoT): A vision, architectural elements, and future directions," Future Gener. Comput. Syst., vol. 29, pp. 1645–1660, 2013.

[6] L. Atzori, A. Iera, and G. Morabito, "The internet of things: a survey," Comput. Netw, vol. 54, pp. 2787–2805, 2010.

[7] A. Bassi, and G. Horn, "Internet of Things in 2020: A Roadmap for the Future," European Commission: Information Society and Media, 2008.

[8] A.K. Evangelos, D.T. Nikolaos, and C.B. Anthony, "Integrating RFIDs and smart objects into a Unified Internet of Things architecture," Advances in Internet of Things, vol. 1, pp. 5-12, 2011.

[9] "Six Technologies with Potential Impacts on US Interests Out to 2025," Disruptive civil technologies, 2008.

[10] A. Alamri, W.S. Ansari, M.M. Hassan, M.S. Hossain, A. Alelaiwi, and M.A. Hossain, "A survey on sensor-Cloud: architecture, applications, and approaches," Int. J. Distrib. Sens. Netw., vol. 2013, pp. 1-18, 2013.

[11] M. Shafie-khah, M. Kheradmand, S. Javadi, M. Azenha, J.L.B. de Aguiar, J. Castro-Gomes, P. Siano, and J.P.S. Catalão, "Optimal behavior of responsive residential demand considering hybrid phase change materials," Appl. Energy, vol. 163, pp. 81-92, 2016.

[12] N. Neyestani, M. Y. Damavandi, M. Shafie-khah and J. P. S. Catalão, "Modeling the PEV traffic pattern in an urban environment with parking

lots and charging stations," PowerTech, 2015 IEEE Eindhoven, Eindhoven, 2015, pp. 1-6.

[13] M. Yazdani-Damavandi, M. P. Moghaddam, M. R. Haghifam, M. Shafie-khah and J. P. S. Catalão, "Modeling Operational Behavior of Plug-in Electric Vehicles' Parking Lot in Multienergy Systems," IEEE Trans. Smart Grid, vol. 7, pp. 124-135, 2016.

[14] N. Neyestani, M. Y. Damavandi, M. Shafie-Khah, J. Contreras, and J. P. S. Catalão, "Allocation of plug-in vehicles' parking lots in distribution systems considering network-constrained objectives," IEEE Trans. Power Syst., vol. 30, pp. 2643-2656, 2015.

[15] M. Shafie-khah, E. Heydarian-Forushani, M.E.H. Golshan, P. Siano, M.P. Moghaddam, M.K. Sheikh-El-Eslami, and J.P.S. Catalão, "Optimal trading of plug-in electric vehicle aggregation agents in a market environment for sustainability," Appl. Energy, Volume 162, 15 January 2016, Pages 601-612.

[16] Horizon 2020 work programme 2014–2015, Industrial leadership, "Leadership in enabling and industrial technologies," Information and communication technologies, 2014, https://ec.europa.eu/programmes/horizon2020/en/h2020-section/leadership-enabling-and-industrial-technologies.

[17] P. Ballon, J. Glidden, P. Kranas, A. Menychtas, S. Ruston, and S. Van Der Graaf, "Is there a need for a Cloud platform for European smart cities?" eChallenges e-2011 Conference Proceedings, IIMC International Information Management Corporation, pp. 1-7, 2011.

[18] G. Suciu, A. Vulpe, S. Halunga, O. Fratu, G. Todoran, and V. Suciu, "Smart cities built on resilient Cloud computing and secure Internet of Things," 19th International Conference on Control Systems and Computer Science (CSCS), pp. 513–518, 2013.

[19] Cloud Project, 2014. http://clout-project.eu/.

[20] R. Petrolo, N. Mitton, J. Soldatos, M. Hauswirth, G. Schiele, et al. "Integrating wireless sensor networks within a city Cloud," Swansity workshop in Conjunction with IEEE SECON 2014, 2014.

[21] S.Y. Chen, C.F. Lai, Y.M. Huang, and Y.L. Jeng, "Intelligent home-appliance recognition over IoT Cloud network," Wireless Communications and Mobile Computing Conference (IWCMC), pp. 639–643, 2013.

[22] D.M. Han, and J.H. Lim, "Smart home energy management system using IEEE 802.15. 4 and zigbee," IEEE Trans. Consum. Electron., vol. 56, pp. 1403–1410, 2010.

[23] X. Ye, and J. Huang, "A framework for Cloud-based smart home," International Conference on Computer Science and Network Technology (ICCSNT), Vol. 2, pp. 894–897, December 2011.

[24] L. Martirano, "A smart lighting control to save energy," IEEE 6th International Conference on Intelligent Data Acquisition and Advanced Computing Systems (IDAACS), Vol. 1, pp. 132–138, September 2011.

[25] M. Castro, A. Jara, and A. Skarmeta, "Smart lighting solutions for smart cities," 27th International Conference on Advanced Information Networking and Applications Workshops, pp. 1374–1379, March 2013.

[26] P. Siano, and D. Sarno, "Assessing the benefits of residential demand response in a real time distribution energy market", Appl. Energy, vol. 161, pp. 533–551, 2016.

[27] P. Siano, "Demand response and smart grids – A survey", Renew. Sust. Energ. Rev., vol. 30, pp. 461-478, 2014.

[28] G. Graditi, M.G. Ippolito, R. Lamedica, A. Piccolo, A. Ruvio, E. Santini, P. Siano, G. Zizzo, "Innovative control logics for a rational utilization of electric loads and air-conditioning systems in a residential building", Energy Build., vol. 102, pp. 1-17, 2015.

[29] P. Siano, G. Graditi, M. Atrigna, A. Piccolo, "Designing and testing decision support and energy management systems for smart homes", J. Ambient Intell. Humanized Comput., vol. 4, pp. 651-661, 2013.

[30] IEA, "Strategic plan for the IEA demand-side management program 2008-2012," IEA Press; 2008. <http://www.iea.org> [accessed 03.12].

[31] H.R. Arasteh, M. Parsa Moghaddam, M.K. Sheikh-El-Eslami, A. Abdollahi, "Integrating commercial demand response resources with unit commitment", Electr. Power Energy Syst., vol. 51, pp. 153–161, 2013.

[32] M. Parvania, and M. Fotuhi Firuzabad, "Demand response scheduling by stochastic SCUC," IEEE Trans. Smart Grid, vol. 1, pp. 89–98, 2010.

[33] "Electricity technology roadmap meeting the critical challenges of the 21st century," EPRI, 2003.

[34] R. F. Arritt, R. C. Dugan, "Distribution system analysis and the future smart grid," IEEE Trans Ind Appl., vol. 47, pp. 2343-2350, 2011.

[35] H. Arasteh, M. S. Sepasian, and V. Vahidinasab, "An aggregated model for coordinated planning and reconfiguration of electric distribution networks," Energy, vol. 94, pp. 786-798, 2016.

[36] G. Zhabelova, and V. Vyatkin, "Multiagent Smart Grid Automation Architecture Based on IEC 61850/61499 Intelligent Logical Nodes," IEEE Trans. Indus. Elec., vol. 59, pp. 2351-2362, 2012.

[37] M. Yun, and B. Yuxin, "Research on the architecture and key technology of Internet of Things (IoT) applied on smart grid," International Conference on Advances in Energy Engineering (ICAEE), pp. 69–72, 2010.

[38] C. Dobre, and F. Xhafa, "Intelligent services for big data science," Future Gener. Comput. Syst., vol. 37, pp. 267–281, 2014.

[39] "The Intelligent Communities of the Year 1999-2010".

[40] Amsterdam Smart City, "Amsterdam Smart City ~ About ASC," Retrieved 2015-05-30.

[41] Ajuntament de Barcelona, "Barcelona Smart City," Retrieved 2015-05-30.

[42] Laursen, Lucas (2014-11-18), "Barcelona's Smart City Ecosystem," MIT Technology Review. Retrieved 2015-05-30.

[43] BCN Smart City, "New bus network," Retrieved 2015-05-30.

[44] BCN Smart City, "Smart traffic lights," Retrieved 2015-05-30.

[45] Ajuntament de Barcelona, "Urban Innovation," Retrieved 2015-05-30.

[46] ICT Regulation Toolkit, "Models for Infrastructure Sharing: Sweden's Stokab," Retrieved 2015-05-30.

[47] Baxter, Stephen (2012-02-26), "Modest gains in first six months of Santa Cruz's predictive police program," Santa Cruz Sentinel. Retrieved 2015-05-26.

[48] W. He, G. Yan, and L.D. Xu, "Developing vehicular data Cloud services in the IoT environment," IEEE Trans. Ind. Inf., vol. 10, pp. 1587–1595, 2014.

[49] R. Petrolo, V. Loscrì, and N. Mitton, "Towards a smart city based on Cloud of Things," Proceedings of the 2014 ACM International Workshop on Wireless and Mobile Technologies for Smart Cities, ACM, pp. 61–66, 2014.

[50] M. Lazarescu, "Design of a wsn platform for long-term environmental monitoring for IoT applications," IEEE J. Emerg. Sel. Top. Circuits Syst., vol. 3, pp. 45–54, 2013.

[51] N. Mitton, S. Papavassiliou, A. Puliafito, and K.S. Trivedi, "Combining cloud and sensors in a smart city environment," EURASIP J. Wirel. Commun. Netw. Vol. 1, pp. 1–10, 2012.

[52] C. Atkins, et al., "A Cloud service for end-user participation concerning the Internet of Things," International Conference on Signal-Image Technology & Internet-Based Systems (SITIS), pp. 273–278, 2013.

[53] D. Corsar, P. Edwards, N. Velaga, J. Nelson, and J. Pan, "Short paper: addressing the challenges of semantic citizen-sensing," 4th International Workshop on Semantic Sensor Networks, CEUR-WS pp. 90–95, 2011.

[54] A. Zaslavsky, C. Perera, and D. Georgakopoulos, "Sensing as a service and big data," 2013. ArXiv Preprint arXiv:1301.0159.

[55] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "Wireless sensor networks: a survey," Comput. Netw, vol. 38, pp. 393–422, 2002.

[56] F. Zhao, "Sensors meet the Cloud: Planetary-scale distributed sensing and decision making," 9th IEEE International Conference on Cognitive Informatics (ICCI), pp. 998, 2010.

[57] J. H. Kim, and A. Shcherbakova, "Common failures of demand response," Energy, vol. 36, pp. 873-80, 2011.