A Composite Structure of ICT for Smart City: Integration Infrastructure and Collaboration Platform

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Abstract— **The urban development vision that is "smart city" is fast becoming a target of modern cities. However, it is hard to find a novel reference model and structural framework to help with the effective and efficient realization of such a vision. This paper puts forward a smart city structural framework in an attempt to address this problem. The suggested framework is based upon two distinctive modelling approaches to design ICT functions to plan a smart city, which in turn is derived from a general model of city spaces and infrastructures. Two modelling approaches are compared by its pros and cons, to combine selectively the promising features together with to derive a novel architecture of ICT function structure for a smart city. A composite model derived through the combinatorial work supports not only the planning of a smart city at a manageable level of granularity (infrastructures) but also the handling of heterogeneous management issues (cross governance and collaboration) to provide convergence services of a smart city**

Keywords— smart city, city infrastructure, collaboration platform, trust interworking, interoperability

I. INTRODUCTION

Currently, no definitive definition exists for the term "smart city"; however, evidence can be found linking the term with references to improvements in a city's quality of urban life and sustainability, as well as an increase in the efficiency of city's systems[1]-[3]. In terms of urban development, "smart city" is more akin to a vision of integrating multiple information and communications technology (ICT) solutions in a secure fashion to manage a variety of assets and business pertaining to a particular city [4]. The use of ICT-based infrastructure deployed alongside the traditional utilities and services of a city will be a rational solution for the development of smart cities especially in viewpoint of city developers'. This type of installation is identified as an (ICT) *infrastructure-focused approach* [5] in light of smart city-planning to add ICT as an additional infrastructure into traditional city structure. In that case the capability of orchestration and integration is concentrated in the newly installed ICT infrastructure, so that the interoperability with traditional city subsystems and the provisioning of citizen centric service are further issued. However, it is generally not easy to achieve interoperability to integrate city subsystems simply by the installation of ICT infrastructure in a smart city, since a city is a highly complex system involving a vast number of people - and thus a huge number of asset flows and infrastructures. For the new service experiments on the citizens' preference is not easy also, so that the services selection through beauty contest are often attached to this type of realization [5].

On the other side of the infrastructure-focused approach, another approach that gives priority to the new socio-economic opportunities of convergence services exists; achievement of quality of city life and innovation of the city spaces are preferentially emphasized in it. In that case the collaboration of various city subsystems is crucial to give synergistic innovation to the socio-economic spaces of a smart city. For the core function of the structural design of ICT for this type of smart city is the collaboration platform working over the smart city service functions and data governances. This type of installation is also identified as (data driven) *service-focused approach* [5] or a holistic view on smart cities [6]. This approach focuses primarily on the synergistic collaboration of traditional city subsystems; therefore the cross-governance among city service and data are taken into account from the early stage of designing ICT platforms. However, this design processes of ICT functions for the collaboration are often hindered by the huge scale and heterogeneity of city subsystems, service functions, social infrastructures, business domains, and stakeholders. To harmonize the strategies or business goals of such subsystems or domains, a smartness in service and data interoperability is required. An implementation in itself could be stuck into an innovative re-organizing process of data models of the business domains of city subsystems and/or a mutual adaptation of service level functions in each subsystem, which will give rise to an excessive tasks for remodeling ICT functions being used in the city subsystems. Consequently, a narrow-downing the scope and scale of implementation is usually applied for the installation of smart city based on this approach. [6]-[8].

The motivation of this paper is to identify and compare the pros and cons of two typical approaches, and to develop a novel structure of ICT implementation that is synergistic enough to provide a promising vehicle for the smart city realization.

II. INTEGRATION INFRASTRUCTURE FOR SMART CITY

Both approaches mentioned above are all based on the general modelling of a city as with the high level definitions of national land space development schemes in countries level [5], which accommodates two different viewpoints; 'citizens centric' and 'city operators centric'. At in the citizen centric viewpoint, a city is a collection of *eco-systematic spaces* that support social and economic activities of their

life. On the other side of it, for the city operators' or governors' viewpoint, a city is a collection of *city infrastructures* that can be grouped into two layers; non-physical and physical supply infrastructures. Those infrastructures shown in the right half of the Fig. 1 are defined as followings:

- Non-physical, social infrastructure: all kinds of social service media supporting citizens' economic and living activities. Governance, welfare, financial, security, medical, all other public city service media are considered as part of this.
- Physical (supply and facility) infrastructure: basic supply and facility necessary for the physical needs of city life. For example, water, energy, and communication are the basic supply infrastructures, and roads, bridges, and parks are typical examples of facility infrastructures [5][7]-[10].

The first case of the approaches we identified in section I, adding an integrated ICT function domain pertaining to ICT infrastructures (see the left half of Fig. 1) alongside the traditional city structures (see the right half of Fig. 1), serves to form an integrated picture of a smart city at a stroke. A promising feature of an ICT infrastructure–focused approach is that to minimize contextual issues relating to an amalgamation with existing city service functions at the time of design and installation of a smart city; for example, requirements relating to cross-governance, coordination for the mash up of existing city services, and revision of legal systems, etc. Such an approach allows for the straightforward launching of ICT infrastructure for a smart city. It is potentially true that the approach advocates the city operators' viewpoint to install accretion *integration infrastructure* to manage efficiently a city with enhanced capability of integrated ICT functions. That is to be in a case of implementing an integrated operation screen in a Mayor's office. However, one may be critical of this approach in saying that the ICT functions in the picture are basically being loosely coupled with traditional city subsystems so that to drive a weak innovation on citizen centric services.

In light of the fact that we consider ICT infrastructure function domain to be an independent entity, it is highly likely that newly launched smart city services will not focus on the convergence city subsystem functions; rather, they will seek to rely only on newly installed ICT infrastructure functions to develop 'centralized, public smart city services' since it is much more practical. To counter such an outcome, two countermeasures are easily considered:

- Provisioning of a smart city service platform that encourages easier access to city data to develop convergence services of smart city.
- Fine selection of citizen-centric services that maximize the effects to the eco-systematic spaces.

Since intervening to the business of city infrastructure operators' is not much practical, rather a process of selecting citizen-centric priority-services is usually applied to improve the effect of the installation of ICT infrastructure. It seeks to exploit ICT infrastructure functions as innovation vehicles, taking advantage of emerging ICT technologies such as IoT, cloud computing, big data, and 5G [11]–[17]; however, this approach still remains a risk of limited effects and weak innovation in traditional city infrastructure functions because of its structural limits. Most of the installation in this case implements an integrated smart city control centre and advanced public services on the city management and surveillance, utilizing newly deployed smart devices and facilities.

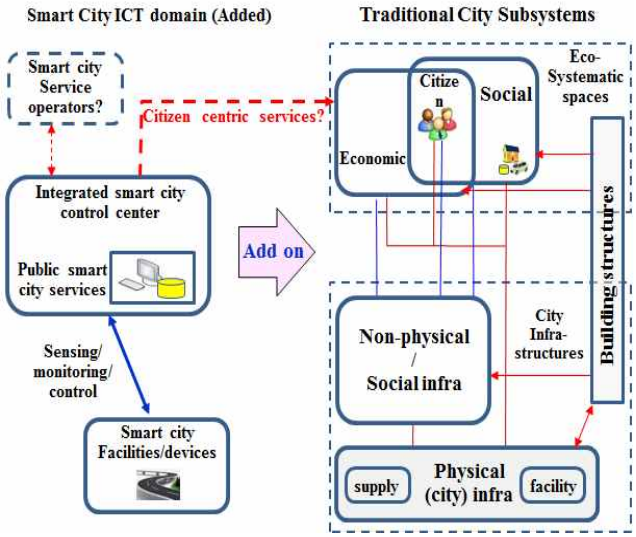

Fig. 1. Approach to deploy an ICT integration infrastructure to establish a smart city.

III. COLLABORATION PLATFROM FOR SMART CITY

In contrast, the *convergence–focused approach* seeks to support an amalgamative realization of a smart city, such an approach would focus more on providing new socioeconomic opportunities as well as efficiency and productivity of a city. Those opportunities that occur as a result of realizations of new services based on inter-domain business interaction and coordination of resources in a city are assumed as to expedite the innovation of city services. This approach is represented, in some cases of city renovation project [6], by the term *holistic view* that implies the city-wide redesign challenges to interconnect the city services and infrastructures holistically for synergistic effects. It naturally builds a frame that focuses on the convergence of data usage in eco-systematic spaces first, since the practical collaboration of service functions in city infrastructure level is generally difficult as well as the approach's basic aim is on the service effects for the citizen's spaces.

A structural framework of such approach can be found in BSI standard publication [18] that it implements a number of concepts: (a) integrated operation of a city, (b) development of innovative citizen-centric services through the operation, (c) delivery of the services via city information market, and (d) citizens to have enhanced delivery channels. Number of European smart city projects adopt most of these concepts [6][19][20], and Fig.2 gives the illustration of a framework in which the concepts in the publication [18] are basically adopted, onto the same city model applied in Section II.

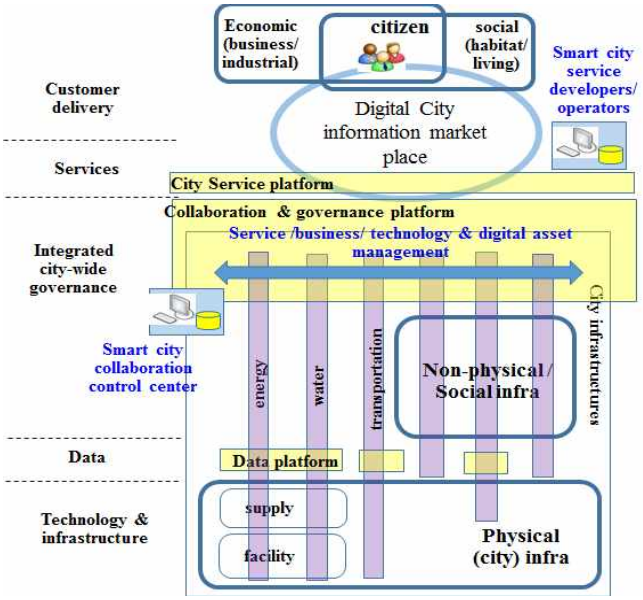

Fig. 2. Approach to deploy the city-wide collaboration platforms to lead holistic convergence and innovative services

Fig.2 shows *A collaboration and governance platform* defined in this paper, which implies a collective form of platform that it composes the core of cross-governance aspect, as experimented in the cases of smart city projects [19][20]**.** The platform provides cross-management functions: (a) service management, (b) business management, and (c) technology and digital asset management, as defined in the publication [18]. *A data platform* underneath the integrated city-wide governance is to collect data from facilities and devices across the city domains, and to link it to any upper layer services; the visibility of the data platform of city operators' is usually very limited so far, but will be open more in the future when standard IoT platforms are widely deployed [21]. *A city service platform* on the top of integrated city-wide governance supports the provisioning of new city services utilising city APIs for cross governance and combination of city data. This feature builds a rich and comprehensive context environment for the innovative new service opportunities for a smart city.

The structure of those platforms actually is well envisioned to support the opportunity of reorganising city functions to enable innovation by convergence, however, it naturally accompanies the complicated control to coordinate the city subsystems to interact with. A number of smart city projects [19][20] corresponding to this approach comes with the limited-scale implementation first, in that reason, such as for a localized deployment in a specific city district to establish an information market place shown in Fig.2. Such localization contributes the efficient implementation of the platforms whilst narrowing the scope and the functional complexity of the platform down to a manageable level of realization.

IV. Comparison of the Structures

Those two approaches described in previous sections, for different types of structural design and technical concepts respectively, are two extremes dominant for the planning of smart city. Comparing the characteristics and strategies of those approaches is beneficial to take a chance to find alternative strategies to compensate weak points and to develop synergistic structures and design concepts. This paper seeks to find promising features of ICT for smart city, which maximise the innovation power and ease of implementation at the same time, through the research on the characteristics of each approach that are identified and compared as in Table I.

TABLE I. Comparison of the approaches focusing on the structural aspects and installation strategies.

categories		Infrastructure focused approach	Convergence focused approach
Technical aspect	Main target of installation	ICT infrastructure	City-wide collaboration and governance platform
	Key technology	Device network, Hardware infrastructure	KPI, SLA, Interworking of Software platforms
	Main focus of technology	City monitoring: surveillance, facility monitoring, traffic control	Creation of new eco-systematic spaces based on the convergence & virtualization
	Design concept	City governors centric	Citizen centric / Service centric
	Operation Stakeholders	City infra operators and administrators	Smart city service operators
	Primary goal / technical achievement	Integrated city control center with advanced data handling	Advanced service platform for new service creation and utilization
	Scale reduction	Limited area, ICT only	Limited space and temporal adjustment
Pros & cons	Implementation efficiency	Good to install in a fast track of adding a new infra to a city	Hard to design cross management functions & to deploy the platform(s)
	Potential draw backs inherited	Isolated ICT infra from traditional city subsystems and service	Diverging scope of cross management & long term availability management
	Counter-measure to the drawback	Citizen centric selection of services (service prioritization)	Limited scale of implementation, feedback mechanism with users
Ch	Place of main effects	Safety and security management in a city	Participatory city service creation accelerated

characteristics	Data acquisition: Device & platforms in action	Mostly newly deployed, such as for a new city. Basically dedicated / private devices belong to ICT control center /smart city operator	Intend to share the data from different infra domains. Interoperability or trust relationship based data platform needed
	interworking between city infra domains	Loose: High (application) level data exchange is mostly considered	Close: Service level interworking can be considered
	Period for the installation	Fixed installation period	Long-term collaboration & adjustment needed

The categories were derived from an understanding of the dominant aspects of those two approaches, as experimented from practical smart city installations, propelled within the studied smart city concepts and structures [20][22]-[25]. The area of the categories for the comparison were for three; technical and structural types, pros and cons in different viewpoints, and other technical characteristics to be issued each other.

The summary in the table simply gives an insight for the characteristics of those two extremes; (a) the *infrastructure focused approach* has a forte to deploy device platform and data acquisition power in a short period, to support city governor centric applications in action, (b) and the *convergence focused approach* gives a chance to realise promising innovation of citizen centric services of smart city, by means of service and collaboration platforms.

V. Amalgamated ICT Structure for Smart City

This paper attempts to merge the ICT structure of those two approaches to achieve synergistic combination, aiming to compensate each approach's weak points — the typical deference of the active convergence of new ICT infrastructure and cross governance mechanism of a city — by fitting the installation of ICT infrastructures and the city collaboration platforms so as to be able to integrate these two approaches under a single structure (see Fig.3) in an effort to enhance awareness and concertation on the part of the approaches. There are number of essential requirements that should be taken for the drawing of coalesced picture of them into account, which come from the motivation of merging two approaches.

First, though the combination of two approaches aims to take advantage of horizontal integration of platforms to share services and data with, but they should keep sovereignty on their own business and assets in secure. It means that the platform integration should be done in the level of service collaboration on the top of 'contract base' business control, while preserving asset and strategic controls underneath.

Second, the citizen centric service platform and city governor centric service platform should keep supporting their own main users and goals, while utilizing enriched resources from others'. It means that the smart city applications in the integrated environment is not in the form of migrated ones on the integrated service platform, but in a kind of mash-ups using imported data and service from other platforms. In an advanced form of this applications will be in an intelligent digital space so called 'data connectome', where data are found and exchanged with intelligence.

Third, data sharing should be more facilitated in between ICT infrastructure and traditional city infrastructure. Newly installed devices and services in ICT integration infrastructure will be based on emerging technology and global standards, so that to generate valuable data in efficiency. Bringing this capability into traditional city infrastructure to utilise is beneficial, and vice versa. However, city infrastructures are usually under conservative regulations that prohibits the open connection to outside. An exquisite mechanism for the cross-domain interoperability to share data and device control is desired, and reflecting the spirit into the coalesced picture is required. A trust brokering mechanism to bridge the infrastructures' data platforms, or a data sovereignty mechanism can be considered.

Fourth, smart city platform should, in any fashion, support city governance and arbitration. As the integration infrastructure we define here is usually installed by the provincial government, it is regarded to have more power on arbitration in a city, than local collaboration platform for traditional city infrastructure operators. The integration infrastructure is expected to play an authoritative role to extend the cross governance and business arbitration in a city, while supporting both for spatial and temporal extent of the scales.

Taking these requirements into account, we set up a new model of ICT structures of smart city (see Fig. 3). The figure is based on Fig.1 and Fig.2 but has an additional modification to address the requirements.

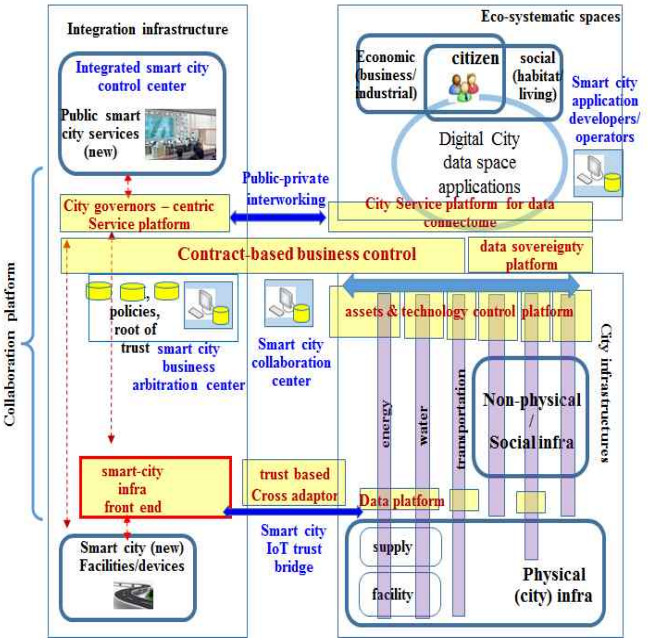

Fig. 3. Model of merging the ICT structures of two different approaches/ design concepts of smart city

The implementation of the requirements on the top of merged Fig.1 and Fig. 2. is as followings:

For the first issue, two parts of ICT functions shown in the left and right side of the Fig.3 are interconnected in the level of 'contract – based business control' platform that provides service level integration while preserving their sovereignty on business each. Each domain has own service platform for service creation; city-governance centric service platform for and city service platform for data connectome.

For the second issue, separate service platforms on the top of business control platform establish the public-private interworking to share resources in the other side. It can be based on the contracts provided by business control platform, or on the management of data and service ownership provided by data sovereignty platform. Shared data and services are exposed to city service platform to enable applications in the form of mash-up or data market for intelligent data exchange.

For the third issue of data sharing among the infrastructures level, this goes primarily for the direction of data sharing from new ICT integration infrastructure to traditional city infra domains' data platforms. Of course this can be done through upper layer integration through business contracts, lower layer direct interworking is also needed such as in case of emergency or temporal association of IoT facilities. An instant association of device and data level collaboration requests trust relationship or access authorities to be in place.

For the fourth issue on the global arbitration of business and governance, ICT integration infrastructure is expected to take a key role of smart city business arbitration centre. When any collaboration between domains are stuck into any difficult and/or strategical decision, the arbitration or judgment control from the central office of city interoperation will be in place. ICT integration infrastructure is to have advanced capabilities including Big-data, root of trust, and Artificial Intelligence to resolve complicate contract situations and cross governance issues.

V. Summary and Future Works

A city, a complex system basically, is hard to simulate using only a simple model on the way to realize the vision of smart city. In this paper, we depicted two extreme cases of modelling ICT structures to install a smart city, and combined them to derive a novel architecture that provides practical efficiency and ideal innovation for the installation of a smart city. Though the *ICT Integration infrastructure* is mostly driven by provincial government and the *Collaboration platforms are* practically supported by industries, configuration for the amalgamation has been successfully done in this paper with careful considerations on the requirements on a composite structure that depicts advantages out of the design. Resulted structure is versatile enough to be used for a new, holistic design of a smart city.

The works for deriving the composite structure give rise to several issues on the design of a smart city. (i) The integrated smart city control centre in many ICT *infrastructure-focused approach* should be subdivided into three parts at least; for smart city infra front end, smart city business arbitration centre, and city governor-centric service platform, as show in the left half of Fig.3. (ii) In the right half of the figure, a citizen-centric service platform is emphasised to provide evolution of city service space to citizens. Service space will be evolved to have intelligence of data availability and data sovereignty under the concept of trusted data connectome. (iii) Two levels of smart city interoperability are recognised. One in the level of public-private interworking based on the contract-based business control platform, and the other is in the level of instant IoT data interworking based on trust bridge or brokers; public-private relation and trust based cross domain adaptor are the key issues for further researches.

We believe our work to develop a composite structure of ICT for smart city will provide a shortcut to anyone seeking to practically design and efficiently realize a smart city.

Acknowledgment

This work was supported by Institute for Information & communications Technology Promotion (IITP) grant funded by the Korea government (MSIT). [R0190-15-2027, Development of TII (Trusted Information Infrastructure) S/W Framework for Realizing Trustworthy IoT Eco-system]

References

[1] Farnaz Mosannenzadeh, Daniele Vettorato, "Defining smart city - a conceptual framework based on keyword analysis", published in TeMA Journal of land use, mobility and environment – special issue on smart city, print ISSN 1970-9889/online ISSN 1970-9870, June 2014.

[2] Lin Xixi, Quan Hua, Zhang Hong, Huang Yinghua, "The 5I model of smart city: a case of Shanghai, China", 2015 IEEE first international conference on big data computing service and applications, 978-1-4799-8128-1/15, 2015.

[3] Leonidas Anthopoulos, Panos Fitsilis, "Exploring Architectural and Organizational Features in Smart Cities", ISBN 978-89-968650-3-2, ICACT2014, February 2014 .

[4] Wikipedia, https://en.wikipedia.org/wiki/Smart_city

[5] Jae Young Ahn, JunSeob lee, Hyung Jun Kim, Dae Jun Hwang, "Smart City Interoperability Framework basd on City Infrastructure Model and Service Prioritization," The 8th International Conference on Ubiquitous and Future Networks (ICUFN2016) , July, 2016.

[6] Jan Peelen, "A Dutch Perspective on Smart Cities," Global City Team Challenge 2016, http://www.slideshare.net/US-Ignite/presentations/2, 2016

[7] Korean Ministry of Land, Infrastructure, and Transport (MOLIT), "The law of planning and use of the land,'2013.

[8] Korean Ministry of Land, Infrastructure, and Transport (MOLIT), "The second phase comprehensive plan of developing ubiquitous city (2014~2018)," 2013.9.

[9] Needs for the U-city, Korea Ubiquitous City Association, http://ucta.or.kr/en/ucity/necessity.php

[10] Korean Ministry of Land, Infrastructure, and Transport (MOLIT), "Final report of U-Eco City Research and Development," 2013.6.

[11] Zaheer Khan, Ashiq Anjum, Saad Liaquat Kiani," Cloud based Big Data Analytics for Smart Future," 6th International Conference on Utility and Cloud Computing, IEEE/ACM, 2013.

[12] Dario Bonino, et al.," ALMANAC: Internet of Things for Smart Cities," 3rd International Conference on Future Internet of Things and Cloud, IEEE, 2015.

[13] Trevor Clohessy, Thomas Acton, Lorraine Morgan," Smart City as a Service (SCaaS) - A Future Roadmap for E-Government Smart City Cloud Computing Initiatives," IEEE ComSoc, 978-1-4799-7881-6/14, IEEE 2014.

[14] Rodger Lea, Michael Blackstock, "CityHub: A cloud based IoT platform for Smart Cities," 6th International Conference on Cloud Computing Technology and Science, IEEE, 2014.

[15] K E Skouby, P Lynggaard, "Smart Home and Smart City Solutions enabled by 5G, IoT, AAI and CoT Services," 2014 International Conference on Contemporary Computing and Informatics (IC3I), 978-1-4799-6629-5/14, IEEE 2014.

[16] Andrea Zanella, et al.," Internet of Things for Smart Cities," IEEE internet of Things Journal, Vol. 1, No. 1, pp22-32, February 2014.

[17] Ignasi Vilajosana, et al., " Bootstrapping Smart Cities through a Self-sustainable Model Based on Big data Flow", IEEE Communications magazine, June 2013.

[18] PAS 181:2014, "Smart city framework – guide to establishing strategies for smart cities and communities" BSI, Department for business innovation & skills, Business Standards Publication, ISBN 978-0-580-81856-1, 2014.

[19] IBM Smarter Cities Challenge, http://smartercitieschallenge.org/ city_negeri_sembilan _malaysia.html

[20] "Montpellier – Replicable Solution: smart technology for smart water", Eang Ang Ong, IBM, 7th World Water Forum MF4.4, 2015.4

[21] oneM2M TS-0001(v2.9.1) Functional Architecture, 2016-7-7, oneM2M,

[22] Aditya Gaura, Bryan Scotneya, Gerard Parra, Sally McClean, "Smart City Architecture and its Applications based on IoT," The 5th International Symposium on Internet of Ubiquitous and Pervasive Things, IEEE, 2015.

[23] Luis Sanchez, Ignacio Elicegui, Javier Cuesta, Luis Munoz, Jorge Lanz, "Integration of Utilities Infrastructure in a Future Internet Enabled Smart City Framework," Sensors, http://www.mdpi.com/journal/sensors, ISSN 1424-8220, 2013.

[24] Anders Monzon, "Smart Cities Concept and Challenges bases for the Asessement of Smart City Projects", International Conference on Smart Cities and ICT Systems (SMART GREENS), May 2015

[25] Jae-Young Ahn, Eunjun Rhee, Hyun-Woo Lee, Dae Joon Hwang, "Cross-conforming Approaches of ICT Functionality Design for Smart City", The 11st International Conference on Ubiquitous Information Technologies and Applications (CUTE 2016), December 2017.