Layered Architecture of Device Virtualization and Functional Collaboration for Efficient Cyber Services Configurability

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***Abstract*—This paper proposes a layered architecture which is well-fitted to provide methodically an environment of configuring collaborative services. The paper also discusses applying the architecture and methodology to design a system of home virtualization and functional collaboration, which is for facilitating emotionally connected presence and emergency services among isolated family members. Finally, this paper presents successful results acquired from system implementation. TTA(Telecommunications Technology Association)'s official test execution results illustrate that the proposed layered architecture and methodology are verified for achieving the goal.**

***Keywords*— Layered architecture, home service, collaborative service, virtualization**

I. Introduction

According to a rapid technological growth, the human living environment is getting automatic, intelligent and smart, while a human life style tends to be more and more personalized, liberalized, self-centered, etc. Such tendency undermines the link of family members especially in home lives, and may result in social problems like accelerating personalized and family-fragmentation, breaking interaction with relative and neighbors, etc.

Both evolution of information and communication technologies and spread of broadband internet can be well-disposed toward alleviation of such problems. They can provide not only a cyber space to share simultaneously but also speedy and useful ways to interact or intercommunicate with other members. They can make secure, convenient and joyful lives possible through re-linking of family members.

Various technologies have been developed for the home domain, which are mostly related to home network or smart home. The first stage has service support platform and intra-home communication technologies, while the second stage has device and service convergence technologies based on context-aware consumer devices. Ubiquitous home services with intelligent consumer devices come to the third stage. Such automation and convenience for human home life, however, result in sometimes breaking communication with other family members. Therefore, it not only strongly demands but also is inherently worthwhile to recover the link of family members.

In order to do so, a new methodology is in demand. The methodology has to combine existing technologies to constitute effectively sound home services. When new concepts or technologies emerge, the methodology also has to adopt and integrate methodically them with existing infra. In addition, in spite of such social trends and problems as described above, the methodology should be possible to maintain the system infra of family-centric quality home lives.

This paper proposes a layered architecture which is methodically applicable to design home service systems. The proposed architecture can meet such methodological requirements as combining, adopting, integrating, maintaining, etc. This architecture and methodology has been applied to design a system of home virtualization and functional collaboration, which is for facilitating emotionally connected presence and emergency services among isolated family members. Results of design and implementation are also presented. Both results and evaluation test results are presented to verify the proposal and design.

This paper is organized as follows. Section 2 describes related works and technologies. In Section 3, this paper proposes a layered architecture. Applying the proposed architecture to design a home virtualization and functional collaboration system is discussed in Section 4. Section 5 presents results of system design and implementation, and discusses verification of the proposal and design with evaluation tests. This paper is concluded in Section 6.

II. Related Works

The purpose of the proposed layered architecture is to provide a methodology of formally configuring services through virtualization and functional collaboration. Thus both virtualization and such applied technologies of virtualization as virtual home services, home cloud services, application services with virtualizing IoT(Internet of Things) devices, etc. are related works to this paper.

In addition, this paper takes into account cyber home services as an applicable instance for the verification of the proposed architecture and methodology. Smart home or home network, therefore, are related works to this paper. However, cyber home services are especially associated with such recently remarkable issues as IoT based smart home, applications of home cloud computing, sharing sensibility between family members, ICT(Information and Communication Technology) for assisted living services, etc. rather than the outdated.

ASF(Acceleration Studies Foundation) presented a "Metaverse Roadmap: Pathways to the 3D Web" as a technology that reflects a device manipulation in a virtual domain to real lives[1]. Cloudlets include new cognitive assistance applications that will seamlessly enhance a user's ability to interact with the real world around him or her. M. Satyanarayanan first introduced the cloudlet concept[2], and Carnegie Mellon University developed a prototype system through a research project. Lee introduced the SVM(Sensor Virtualization Module) which virtualizes external sensors so that smartphone applications can easily utilize a large number of external sensing resources[3].

Some studies have approached in particular using virtual environments for psychological treatment or healthcare. Parsons researched such a retooling approach using virtual environments that were originally developed as a controlled stimulus environment in which cognitive processes could be systematically assessed in persons with various neurocognitive and affective deficits[4]. D. Holloway proposed three aspects of applying virtual worlds to health or healthcare areas[5]. Ana researched how virtual worlds have been and are being used for the prevention and treatment of addictive behaviors related to substance abuse[6].

W. Brunette presented a framework, called ODK(Open Data Kit Sensors) as a sensor integration framework at the application level[7]. The framework simplifies both application and driver development with abstractions that separate responsibilities between the user application, sensor framework, and device driver.

The bmcoforum developed a generic business model of mobile services for seamless audio-visual content consumption, which include a convergence architecture in a variety of dimensions: at marketing level, at device level, at network level, at the service platform level, and at content level[8].

IBM introduced a new paradigm of smarter home[9]. Compared with previous attempts to enable the smart home, the intelligence and the complexity in the new smarter home is moved out from the home onto the network, or more precisely the Internet cloud. Garcia promoted to use cloud computing at home area for managing smartly home electricity[10]. Through the Internet it can collect on-line data power consumption, and can manipulate the power supply of the connected electrical appliances. Kirkham, et. al. researched how cloud service management principles of risk and contextualization for virtual machines can produce solutions to emerging challenges facing a new generation of smart home devices[11].

Providing technologies of collaborating sensors or devices can enable family members even isolated apart experienced with living at the same space. The technology can also enable sharing sensibility between family members apart. Goodnight Lamp[12], Pillow Talk[13], LivelyGram[14] can share their presence and availability with their family members easily.

The web-based IoT platforms are actually in service with IoT technologies and products. Xively by LogMeIn offers an IoT platform as a service, business services, and partners that enable businesses to quickly connect products and operations to the Internet[15]. SensorCloud is a unique sensor data storage, visualization and remote management platform that leverages powerful cloud computing technologies to provide excellent data scalability, rapid visualization, and user programmable analysis[16]. IOBridge provides solutions for easily connecting any product to a mobile device using the web[17].

An assisted living residence or assisted living facility is a housing facility for people with disabilities. The AAL(Active and Assisted Living) Programme aims to create better conditions of life for the older adults and to strengthen the industrial opportunities in Europe through the use of ICT. The Programme presented successful results from various area projects such as co-living and connected vitality[18][19].

III. Proposed Architecture

A. *Basic concept of the Layered Architecture*

In order to design a system of virtualization and functional collaboration, we introduce a concept of the layered architecture illustrated in Fig. 1. The layered architecture consists of three layers. The lowest layer of the architecture is a physical layer which contains all physical devices and sensors, and other elements which are resided in physical domain and involved in target services.

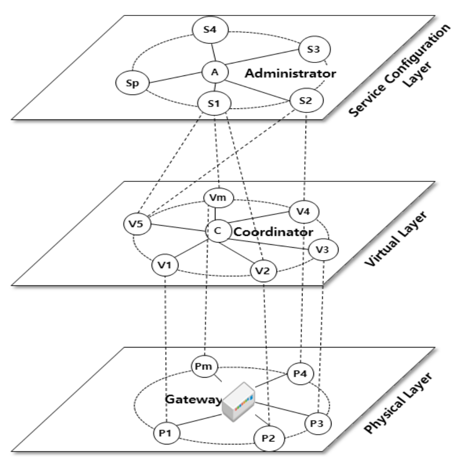

Figure 1. Concept of the layered architecture

All elements in the physical layer are connected to the network so as to be accessible by the system. An element of this layer is in operation, and so continuously varying in natural situation. Sensors adopted in the element acquire data values with sampling natural situations time-periodically. This layer thus performs to extract discrete data from physical operations in natural situation, which is transferred to the next virtual layer.

The middle layer is a virtual layer which includes virtualized elements of physical layer elements in an 1:1 manner. This means that the layer consists of a number of models abstracted from elements of the physical layer. A model abstractedly mapped into a physical element includes a set of states which represent situations of the mapped one. The state is set up with updating data which is periodically transferred from the physical element. A change of any state invokes designated services of the top layer, which can account for the situation that causes the state change. This layer also contains software functional elements required for composing user services. A set of virtual layer elements combine to constitute a virtual node. It becomes a basic object for providing user services.

The top layer is a service configuration layer in which various user services are constituted with combining a set of required virtual layer elements. A user service can be composited with any collaborated combination of virtual layer elements. State changes of the virtual layer awake designated user services in this layer. Table I shows comparison of features of each layer.

This layered architecture can present a structural and formal methodology with which we can achieve completeness in system design. It means that the methodology can alleviate a possibility of not only omitting any element required to consider but also any error or mistake in configuring service operations. The architecture can also provide the reliability for system design so that each operation in configured services is well consistent to real action in the physical domain. Virtualization of physical elements makes them manipulated in the cyber domain in which sound services can be inspired with no regards to time and space.

TABLE I. COMPARISON OF LAYER FEATURES

	Layer 1	Layer 2	Layer 3
Position	physical	virtual	service
Method of building next layer	abstraction	configuration of service	-
Information Conversion	signal to sensed data(event) $A \rightarrow E$	data(event) to state $Q \times X(e) \rightarrow Q$	state to service $Q \rightarrow S$ $S \rightarrow Y(e)$
Networking	physical network	functional binding	framework
Transfer to next layer	sensed data	state	-
element of constitution	devices including sensors	models, software functional elements	user services

The proposed architecture is so flexible and methodical as to effectively adopt any changes in element, functionality, service configuration, etc., which may be required in the future, without serious deprivation of completeness and reliability. In addition, this architecture can support such efficiency as easiness, structural mechanism, less effort, etc. for system design and development. Such characteristics makes easy not only functional modifications or additions but also validation and verification in system design.

This layered architecture thus can provide a structural and formal methodology so that system design for virtually collaborated home and services can achieve the quality of being complete and highly reliable.

IV. APPLYING TO CYBER HOME SERVICE

A. *Home Service Based on Proposed Architecture*

Fig. 2 illustrates the operation and configuration concept of a home autonomous service as one application of the layered architecture. The home domain in the physical layer consists of various home devices, and each device employs one or more sensors. Elements in the virtual layer are abstraction models of physical devices. Each device in the physical layer corresponds with a clone element, noted *Vc* in Fig. 2, in the virtual layer in an one-to-one manner. When the given situation of the device is changed, a sensor acquires situated data and transfers them as events to the corresponding clone of the virtual layer. For an instance in Fig. 2, a door sensor, a bed sensor, and a light switch sensor located in the home domain of the physical layer send events of *open/close*, *empty/occupy*, and *on/off* to the clones of *Vc1*, *Vc2*, and *Vc3*, respectively.

In the virtual layer, an associated element, noted *Va* in Fig. 2, composes multiple clones as necessary which contains events newly updated. The associated element also includes simulated elements, noted *Vs* in Fig. 2, if the occasion arises. The associated element then derives a state of the device or the

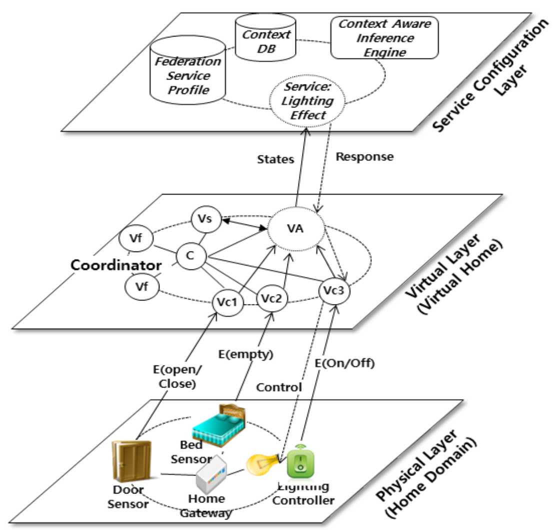

Figure 2. One application of the layered architecture: home autonomous service

domain with a set of events. For an instance in Fig. 2, *Va* is composed of *Vc1*, *Vc2*, *Vc3*, and Vs, and derives the state of "*Light ON with nobody inside*" from multiple events of *close*, *empty*, and *on*.

A state transferred from an associated element invokes a designated service in the service configuration layer. The invoked service is in execution of designated routines, and responds if the occasion arises. For an instance in Fig. 2, the state of "*Light ON with nobody inside*" invokes the service of "*Lightening Effect*", and responds during the service. The response, for example in this case, controls the light off through the associated element *Va* and the clone *Vc3*. The service can be configured variously in this way. This flexible and methodical framework can provide higher reliability, easiness, less deficiency in system design or development.

Fig. 3 shows another application of the layered architecture, which is for a collaborative home service. This service includes more than one physical and virtual home members in order to be collaborated in service operations. As show in Fig. 3, two sorts of sensors transfer their acquired events to the corresponding virtual element, and then the virtual element derives the state that is sent to invoke a designated service in the service configuration layer.

During executing the service can respond that it is to control devices belonging to another physical home domain. This means that two sorts of physical homes are together in collaborative service execution through the layered architecture. A user in a physical home domain can efficiently manage and control devices affiliated to another physical home domain. Such a collaborative service is typically useful to implement assisted living operations for the old or disabled that requires other's help to deal with something to do.

V. System Design and Implementation

A. Implementation of System

Based on the proposed architecture and methodology, the service system can be implemented methodically and home services can be configured variously. An assisted living service is one typical example of which the methodology is applicable and so collaborative service configuration environment can be favorable to implement it.

Fig. 4 illustrates a collaborative service scenario for assisted living based remote safety care of isolated family members.

The service includes three components such as parent's and son's homes in the physical domain, federation of virtual big family home in the virtual domain, and service system network. The federation of virtual big family home constitutes three layers as proposed, which are a physical layer, a virtual platform layer, and a service layer.

For the first step of this service, a physical device like a camera senses the situation that certainly demands some assistances or helps. The device then transmits the sensed data to the service system in real time. The system either responds autonomously with designated procedure depending on context awareness or forwards the situation data drawn by context awareness as a request of collaborative service to the u ser device affiliated to son's home.

The user in son's home can recognize the situation of parents with alarming user device, monitoring remotely, or analyzing the context data. Upon recognizing it, the user has to decide processes of handling this situation. If it is emergent, the user responds to handle collaboratively with such public assistants as 119, safety guards, public security services, etc. The system then dispatches a national security service to resolve rapidly the situation.

Assisted living services can be spread over anyone who needs temporal or permanent assistance. They are the young alone temporally, the injured, the sick, the old, the disabled, the handicapped, and so on. For those various types of assisted living services can includes monitoring in-home situations and states of home devices, context awareness with living patterns and behaviors, forwarding the situated data, control home devices depending on the situation, and responding to the needs of the occasion. Collaborative service configuration environment is favorably applicable to most of such a wide range of assisted living services. Therefore the layered

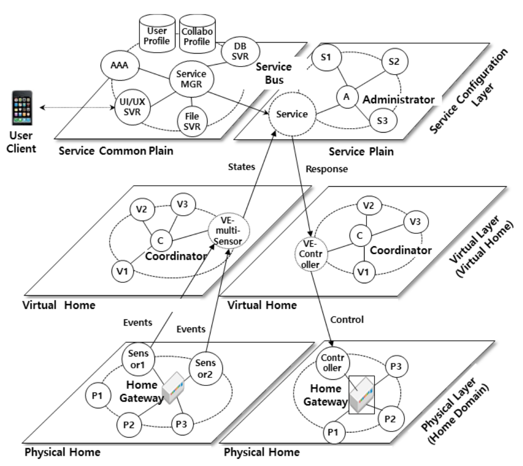

Figure 3. Application of the layered architecture: collaborative home service

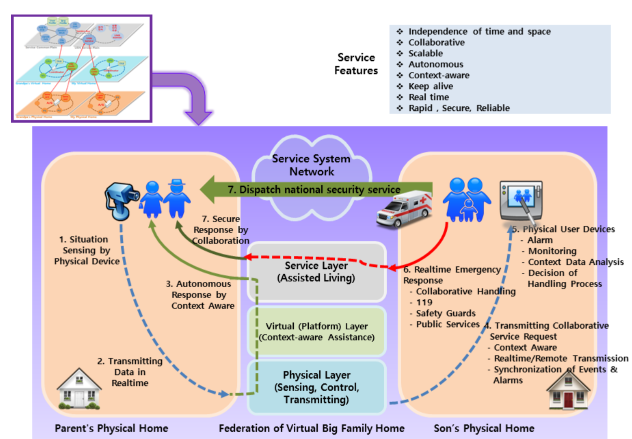

Figure 4. A collaborative service scenario with the layered architecture

architecture and methodology proposed in this paper are suitable to provide such convenient home services.

Fig. 5 shows implemented architecture of the service system, which consists of three such layered functionalities as physical, virtual, and service. The physical layer functionality includes device interface manager and communication interface manager. The virtual layer functionality is composed of virtual device manager, virtual network manager, communication & police manager, and collaboration service coordinator. Service middleware and library combine to constitute the service layer functionality.

B. *Test for Verification*

The proposed architecture can be proved by implementing a system of home virtualization and functional collaboration which is for facilitating emotionally connected presence and emergency services among isolated family members. At a functional point of view, the implemented system was testified successful with respect to typical cyber home service scenarios. Performance evaluation of the system becomes an essential point for verification of the proposal.

Table II illustrates test factors evaluating performance of the implemented system, which are set for verifying the proposed architecture. The virtual layer composites a set of virtual homes, and a virtual home includes a set of virtual elements, abstracted models, which corresponds with physical devices in an 1:1 manner.

The factor #1 evaluates an ability of the virtual layer service system which composes virtual homes and manages, operates, and controls them. In order to test the ability, a simulator which can simulate behaviors of hundreds of virtual homes is applied. The factor #2 evaluates an ability of the server system that is in charge of all user services. In order to test the ability, a simulator which can simulate behaviors of user connection trials is applied. The factor #3 evaluates an ability of the system to recognize correctly the safety contexts. In order to test the ability, a simulator which can simulate possible safety contexts is applied. The factor #4 evaluates the time delay of operations in the system between the physical and virtual layers. In order to measure the time, a log file which maintains historic records of the system operations is

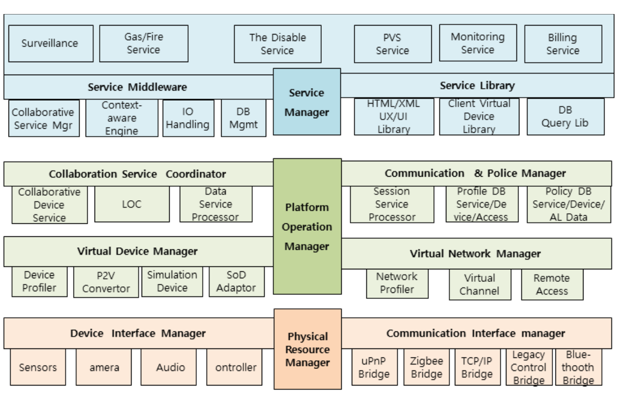

Figure 5. Implemented architecture of the service system

TABLE II. TEST FACTORS FOR EVALUATING PERFORMANCE

Evaluation Factors	Unit	Description	Test Result
1. Number of Virtual Homes Simultaneously Supported	EA	Means that how many maximum number of virtual homes the virtual layer can simultaneously support.	1,502
2. Number of User Agents Simultaneously Connected	EA	Means that how many maximum number of users are possible to connect simultaneously to the server system.	5,101
3. Rate of Safety Context Recognition	%	Means that how much rate the system can recognize successfully the safety contexts.	94.93
4. Time for Recognizing Resources Virtually	sec	Means that how long it takes to update the corresponding state in the virtual layer since a sensor operates in the physical domain.	0.16
5. Synchronization of Collaborated Data	ms	Means that data which devices involved in collaboration generate have to be synchronized.	34.7

investigated. And the factor #5 means that data which devices involved in collaboration generate have to be synchronized. In order to verify the synchronization, the time difference between two different display monitors which the same server streams contents over the system is measured.

Fig. 6 shows a testbed configuration diagram which is applied for the evaluation test of the implemented system. Executing the evaluation test for five factors in such ways as described above has produced the results as presented in last column of Table II.

C. *Observations*

All evaluation tests are officially requested to TTA, which is a Korean government organization of providing testing and certification services especially in four such key ICT fields as networks, software, broadcasting, and mobile communications.

Last column of Table II illustrates TTA's test execution results of five such evaluation factors as described above. In addition, such home devices in the physical domain as sensors of CO, VoC, smoke, temperature & humidity, gas valve switch, doorlock, smart plug, etc. are included in the implemented system, and actually mobilized to test five evaluation factors.

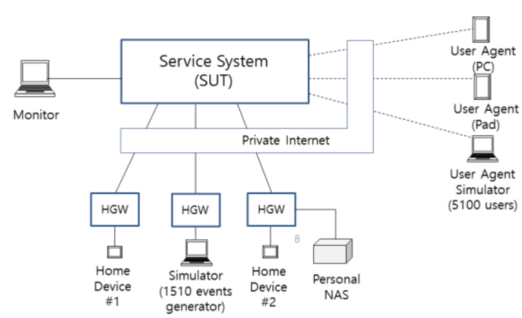

Figure 6. Testbed for evaluation test of the implemented system

Those results illustrate a successful performance in all five test factors of the implemented system. Due to applying them to service system design and implementation and acquiring successful results from TTA's official evaluation tests, it is observed that the proposed layered architecture and methodology is verified for achieving the goals.

VI. Conclusions

A modern tendency to be personalized or self-centered according to a rapid technological growth undermines the link of family members especially in home lives, and may result in social problems. However, both recent evolutions of information and communication technologies and spread of broadband internet can be well-disposed toward alleviation of such problems. In order to do so, a new methodology is in demand, which can combine existed technologies to constitute effectively sound home services, and also adopt and integrate methodically emerging technologies with existing infra. Being strongly in demand and inherently worthwhile to recover the link of family members, the methodology should provide a sound system infra for family-centric quality home lives.

In this paper a layered architecture, which is methodically applicable to design home service systems, is proposed. The proposed architecture can meet such methodological requirements as combining, adopting, integrating, providing, etc. The layered architecture consists of three layers: physical, virtual, and service configuration. This layered architecture can present a structural and formal methodology so that we can achieve completeness in system design. It means that the methodology can alleviate a possibility of not only omitting any element required to consider but also any error or mistake in configuring service operations.

This paper presented how the layered architecture is well-fitted to provide an environment of configuring services collaboration, and illustrated for instance that the collaborative service configuration environment is favorably applicable to various assisted living services. Therefore the layered architecture and methodology proposed in this paper are suitable to implement such a virtual service as cyber home services. The paper has applied the architecture and methodology to design a system of home virtualization and functional collaboration, which is for facilitating emotionally connected presence and emergency services among isolated family members, and acquired successful results from system implementation.

For verification of the proposed architecture, performance evaluation of the implemented system is also valuable. The paper set five evaluation test factors for verifying the proposed architecture. TTA has officially executed all evaluation tests of which results illustrated a successful performance in all five test factors of the implemented system. This means that the proposed layered architecture and methodology is verified for achieving the goals.

References

[1] http://metaverseroadmap.org/index.html

[2] Thomas D. Parsons, "Virtual Simulations and the Second Life Metaverse: Paradigm Shift in Neuropsychological Assessment," Virtual Worlds and Metaverse Platforms: New Communication and Identity Paradigms (by Nelson Zagalo, et, al, Chapter 16), IGI Global, 2012.

[3] David Holloway (Metaverse Journal, Australia), "Virtual Worlds and Health: Healthcare Delivery and Simulation Opportunities," Virtual Worlds and Metaverse Platforms: New Communication and Identity Paradigms (by Nelson Zagalo, et, al, Chapter 17), IGI Global, 2012.

[4] Ana Boa-Ventura (University of Texas at Austin, USA), "Virtual Worlds and Behavioral Change: Overcoming Time/ Space Constraints and Exploring Anonymity to Overcome Social Stigma in the Case of Substance Abuse," Virtual Worlds and Metaverse Platforms: New Communication and Identity Paradigms (by Nelson Zagalo, et, al, Chapter 18), IGI Global, 2012.

[5] Mahadev Satyanarayanan, Paramvir Bahl, Ramon Caceres, and Nigel Davies, "The Case for VM-Based Cloudlets in Mobile Computing," IEEE Pervasive Computing, Vol. 8, Issue. 4, pp.14 – 23, Oct.-Dec. 2009.

[6] Byung-Bog Lee, SangGi Hong, Kyeseon Lee, Naesoo Kim, and JeongGil Ko, "Efficiently Managing Collected from External Wireless Sensors on Smart Devices Using a Sensor Virtualization Framework," Information and Communications Magazine, The Korean Institute of Communications and Information Sciences, Vol. 30, No. 10, Sept. 2013.

[7] W. Brunette et al., "Open Data Kit Sensors: A Sensor Integration Framework for Android at the Application-Level," Proc. ACM International Conf. Mobile Syst., Applications, and Services (MobiSys), June 2012.

[8] Herbert Mittermayr and Claus Sattler, "Mobile Services for Seamless Audio-Visual Content Consumption Services Examples and Business Model Considerations," The Report of Broadcast Mobile Convergence Forum, Sept. 2009.

[9] IBM, The IBM vision of a smarter home enabled by cloud technology, White Paper, 2010.

[10] Marvin R. G. Garcia, Hannah R. B. Chan, Benilda E. V. Comendador, Grant B. Cornell, Christopher D. Celestial, and Arc E. P. Mercolesia, "Smart Home Electricity Management System Using Cloud Computing (SHEMS)," Journal of Advances in Computer Networks, Vol. 1, No. 1, March 2013.

[11] Tom Kirkham, Django Armstrong, Karim Djemame, Ming Jiang, "Risk driven Smart Home resource management using cloud services," Future Generation Computer Systems, Volume 38, pp. 13–22, September 2014.

[12] http://goodnightlamp.com/

[13] http://www.dailymail.co.uk/sciencetech/article-2294009/Good-night-The-internet-connected-lamp-lets-share-bedtime-loved-ones-world.html

[14] https://www.mylively.com/

[15] https://xively.com/

[16] http://www.sensorcloud.com/

[17] https://iobridge.com/

[18] http://www.aal-europe.eu/co-living/#sthash.Eqz2m8iN.dpuf

[19] http://www.aal-europe.eu/about/success-stories/connected-vitality/#sthash.PUlFXuDJ.dpuf