Space Model for Autonomic Service Providing in Ubiquitous Smart Space

Euna Choi
Department of Electrical and Computing Engineering
Ajou University
Suwon, Korea
camove@ajou.ac.kr

Changgyu Bak
Department of Electrical and Computing Engineering
Ajou University
Suwon, Korea
pck0912@ajou.ac.kr

Jung-Won Lee
Department of Electrical and Computing Engineering
Ajou University
Suwon, Korea
jungwony@ajou.ac.kr

Abstract—**Most of the location awareness are focused on human location. Even if these consider the device location, they deal with the location of mobile devices using the coordinates (x,y). However, the ubiquitous smart space includes home appliances such as a humidifier, a heater, or a lamp as well as a smart phone or a laptop. The smart space must recognize the device location as a physical space such as a living room or a printer room rather than the coordinates. In this paper, we propose a new space model for autonomic service providing in ubiquitous smart space. It defines the types of a space and a device and suggests the space management method for autonomic service providing. We also implemented an embedded system, SM(Space Manager), and applied it to the test bed for intelligent home network.**

Keywords-Ubiquitous Computing; Autonomic Computing; Smart Space; Device Location Awareness

I. INTRODUCTION

Ubiquitous Smart Space (USS) is a user-centered convergence space which has characteristics of situation-awareness, autonomic cooperation, and self-growing [1]. When the specific goal is issued by situation-awareness, USS discovers the effective services and binds adequate devices needed to perform the services. At this time, the service execution is dynamically controlled according to the context. Among the context, the location awareness such as where the service is issued and the bound devices exist is core information for autonomic service providing. Autonomic computing is to develop computer systems capable of self-management, to overcome growing complexity of computing systems, and to reduce the barrier that complexity poses to further growth with hiding these process to users [2]. In USS, autonomic execution of necessary smart devices is indispensable to provide user-adapted services. All devices of USS are operating to achieve the goal of services and the binding between a device and a service must be performed without the user's intervention [3].

Recently, there are some techniques for indoor location awareness with indoor GPS [4], Tagging, Sensing [5, 6], and Grouping with IP information. Since these are focusing on finding location of human or hand-held devices such as cell-phone, there are some problems in order to support customized and autonomic services in USS.

First, the definition of our smart space, USS, is different from points represented on the coordinates. USS is a user-centered convergence space, for example, a space suitable for sleeping, 'for exercising', or 'for working with digital equipments'. It is not important whether the space for sleeping is pointed by (x1, y1) or (x2, y2). Figure 1 shows a home as an example of a convergence space.

Mr. John sometimes sees a movie as a multimedia service in his living room which is equipped with a TV and A/V and maintains optimal temperature and illumination by an air conditioner, a curtain, and a lamp. He also takes a sleeping service in his bedroom which is a comfortable environment supported by a humidifier, a lamp, and so on. At this time, there are two physical spaces, a bedroom and a living room at John's home. If he wants to take a new service 'for relaxing' mixed of two services, 'for sleeping' and 'for multimedia service' in his living room, the convergence space starts to bind devices enabling to make an environment for relaxing. Here, the humidifier and the aroma machine may be moved from his bedroom to his living room and the function of his living room is extended to the logical space to be able to sleep. Therefore, we need a technique to recognize the physical and logical space rather than coordinates.

Second, the existing location awareness is focusing only on detecting the device location but does not have any management method for newly registered, withdrawn, and moved devices. They cannot consider how the services are affected by the movement and the registration of devices because they have no space model which supports a convergence space including human, services and devices. In Figure 1, if the humidifier is moved to the living room for a relaxing service, the service to adjust humidity in a bedroom cannot be operating.

Therefore, we have to develop a space model which enables autonomic service providing in USS. We first define the types of a space and a device and suggest the space management method for devices. We also implemented an embedded system, SM(Space Manager) based on our space model, and applied it to the test bed for intelligent home network.

The remainder of this paper is organized as follows. Section 2 describes background and section 3 presents requirements of space management method. Section 4 proposes a new space model to provide autonomic services.

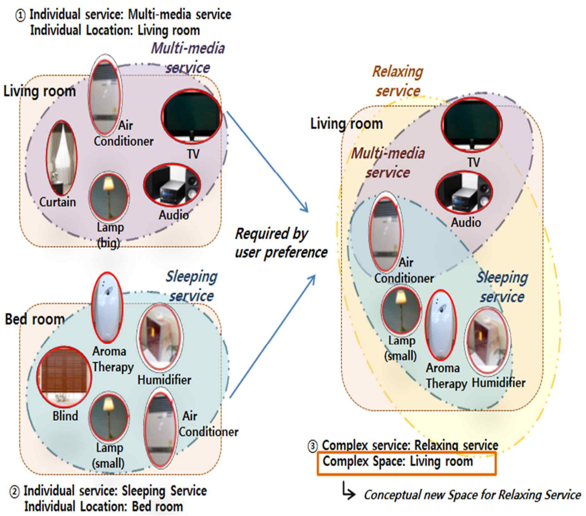

Figure 1. The Relationship between Services-Users-Spaces in Ubiquitous Environment.

Section 5 shows the implementation and its experiments and section 6 concludes the paper.

II. Related Work

The USS has distinct characteristics which are different from normal spaces' in general structures. In USS, the space has to provide user-customized services. These smart services are not available in general structured spaces. Since the demand of service from users is appeared, the special technique needs to support the service with user requirements in USS. Most of researches are concentrated on the movement of space objects as space events. The space object is the primary element and a member of a space. It is widely divided into devices as operators and human as users. Table 1 shows a comparison with these researches.

Recent researches make the localization data by using indoor GPS, tracking with various sensors, and RSSI system. These consider the movement of space subjects as a space event. Since the space events make some changes in the circumstance, these events are used for the context information. The indoor GPS system [4] improves a problem that it is not possible to take signals inside from GPS satellites. This system experimentally mounts pseudolites which detects an accurate position of objects in indoor areas. Sensor detecting systems use ultra-sonic sensors and beacons [5]. They estimate the direction of a mobile object by using a digital compass also [6]. For wide spaces, some researches implement a wireless sensor network based on the ZigBee standard and measure RSSI [7]. Moreover a few studies detect and process the movement of objects in flexible unit space by using Atlas systems [8]. The methods generate the knowledge which is only simple positioned coordination represented a focused target. These location tips are without any information or consideration of related to provide services. We need to contemplate a new localization method for offering services to users.

Some studies try to realize the indoor location-oriented service by combining a location technology and hierarchical room-based location modes [9, 10]. However they cannot fulfill user satisfaction of operating autonomic services, even they consider a relationship between service spaces and devices. Therefore a new technique is necessary to connect space elements and service information tightly. It lets services be autonomic in USS.

The BIM (Building Information Modeling) [11] considers the information of areas geometrically. It makes data base about a facility to build and to repair this. However, by BIM, users can receive only few services restricted in built areas because it focuses on buildings only and not considers how to offer services. Since a service should content user's request with no limitation given by geometric spaces, a new approach is needed to manipulate autonomic service space.

Almost methods have difficulties to achieve the service aim which is autonomic and self-binding by connecting organically between spaces and users. As shown in Table 1, these systems are only focused on the notification of the device movements or specific space information. Therefore, we should design a new space management model for managing and providing user-centered services considering characteristics of USS.

TABLE I. Comparison of Characteristics in Various Systems for Space

Items	Indoor Location Method			BIM
	Indoor GPS	Tagging	Sensing	
Space Diversity	Non	Non	Non	Insufficient
Autonomic Management	Non	Non	Insufficient	Insufficient
Pre-knowledge	Necessity	Necessity	Necessity	Necessity
Subject of Events	Objects	Tags	Objects	Careless
Mobility of Objects	High	High~Low	High	Careless
Space Algorothm	Existence	Insufficient	Insufficient	Non
Location Tracking	Available	Available	Available	Non
System Complexity	High	High~Low	High	Medium

III. Requirement of Space Management Method

A. The Requirement for Variety of Managed Space

Existing space concepts are mostly not proper to support ubiquitous services. The space is physically divided into a size or an area. In general, the space is physically divided by a solid such as walls, pillars or doors. Every event and operation is not able to effect on the area which is out of a defined individual space. When a user wants a few services, he is blocked physical limitation by the position where he is. However since the goal of USS service is to provide every service for satisfying user requirements by using unconstrained binding with all potential resources, a novel concept of space should reflect following specifications.

- A concept of space has to consider how to provide services.

- The division standard of space should be defined by a range of service affected rather than such physical barriers (walls, pillars) or a size.
- A space should be accomplishing a goal of a service.
- A space is possible to be easily modified in forms which have various range or properties.

B. The Requirement for Providing Autonomic Services

The most important issue is how we can satisfy user requirements. We should focus on how to manage services with proper devices. We have to figure out what devices are ready and where they are. Although other studies suggest various indoor location awareness methods, these do not fit in the service environment in USS.

These systems produce some coordination of objects on pre-informed maps or blueprints, so complex infrastructures and informations are needed. Thus, the new device location awareness method should satisfy following requirements.

- It should offer the information related with services. It includes the data about what appeared services rather than location notes as positioned coordinates of devices.
- It should notify whether a detected device can offer services.
- It informs what devices can be bound and what service status they have.
- The location information has to follow the idea of space in USS.
- It should be able to detect space events by device movements or inflows in real time.

IV. SPACE MODEL

A. Space Type in USS

We suggest the new concept of spaces for providing services without any physical limitation. It makes proper types of space and they depend on the situation of offering service.

Firstly, we define the space as a physical space and a logical space. It supports that a user can utilize necessary services through the composition and separation of PSs to LSs by these two space types [12].

- Physical Space (PS): This type means the minimized range of managing space. It is as same as the original constructed format. It is an architectural geometric space and also a unit of a physical division of a space.
- Logical Space (LS): When the original geometry space needs to be modified, LS type is generated. If there is more two PSs and they correspond with each other, or an already composited space wants to separate into spatial pieces, the space becomes LS type. Creating LS is to support user customized service to users with their requirements.

Fig.2 presents PSs and LSs in USS. Spaces are redefined and reclassified by service characteristics depend on occurred service conditions. Using space types is important to offer user - customized services by necessity.

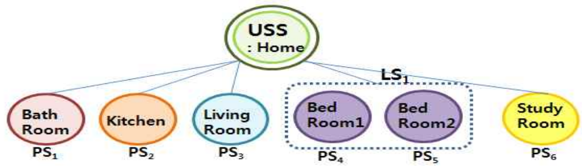

Figure 2. Definition and Classification of PS/LS Space Type in USS.

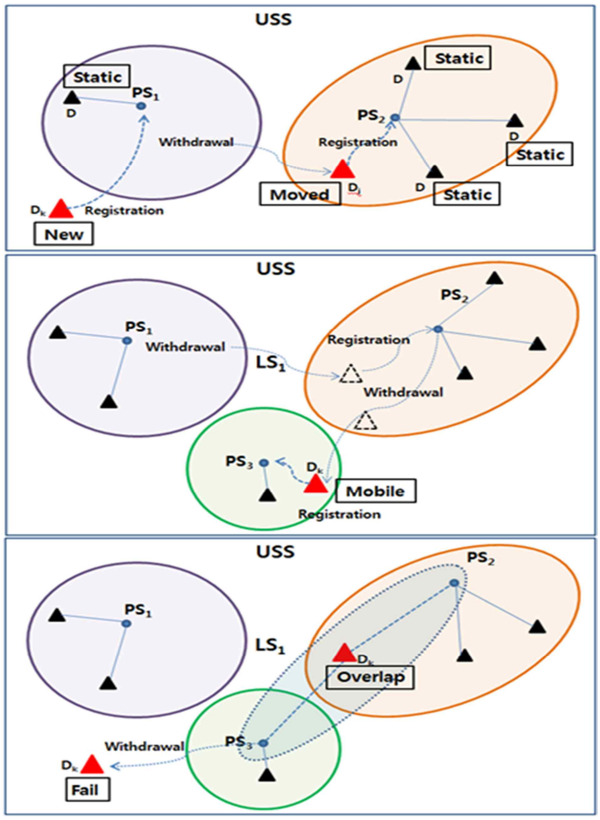

Figure 3. Device Status Types for Device Management: NEW, STATIC, MOVED, OVERLAP, MOBILE, FAIL.

B. Device Status Type in USS

In order to make the PS, LS space types, it is necessary to define types of device statues of each service supplier [13]. By changes of each device's status type, spaces can be the LS type. There are six status types for a device According to the potential scenarios in USS.

- NEW: If $\bigcup_{t=0}^{\delta} \mathrm{where}(D_k, t) = \emptyset$, a certain device is understood 'NEW'. It means that it has never been registered any place before.
- STATIC: We suppose that there is a function 'where'. It is able to calculate the space where D_k stays at time t, and it can be presented as $\mathrm{where}(D_k, t)$. If $\bigcup_{t=0}^{\delta} where\ (D_k, t) = \{PS_i\}$, the status of a certain device is 'STATIC'. It can be shown as $\mathrm{where}(D_k, t) = PS_i^{static}$ and the time t is the current time. If $\mathrm{where}(\mathrm{airconditioner}, t) = PS_3^{static}$ when PS_3= living room, the air conditioner is regarded as settled on a living room for δ statically.

- MOVED: If $\bigcup_{t=0}^{\delta} where\ (\text{dev}_k, t) = \{\text{PS}_i, \text{PS}_j\}$ when $\text{PS}_i \neq \text{PS}_j$, a device's status type is 'MOVED'. If $\text{where}(\text{CDPlayer}) = \{PS_1, PS_2\} = PS_{1,2}^{moved}$ when PS_1=living room, PS_2=kitchen, the CD player seems to be moved to the kitchen from the living room.
- OVERLAP: This means that a device has been registered in two PS at one moment. As shown in Fig. 3, D_k is being registered PS_2 and PS_3 as well. In this case, more than two PSs (PS_2, PS_3) are re-generated as one LS (LS_1).
- MOBILE: If $\bigcup_{t=0}^{\delta} where\ (\text{dev}_k, t)\} = \{\text{PS}_1, \ldots, \text{PS}_n\}$, $(n \geq 3)$, the status type is "MOBILE". It is to offer seamless services for a user with high mobile devices. D_k is moving PS_1, PS_2, and PS_3 in USS continuously.
- FAIL: If $\bigcup_{t=0}^{\delta-1} where\ (\text{dev}_k, t) = \{\text{PS}_1, \ldots, \text{PS}_n\}$ and $\bigcup_{t=\delta}^{2\delta} where\ (\text{dev}_k, t) = \emptyset$ $(n \geqslant 1)$, at $t + \delta$, the status of D_k is defined "FAIL". The system remembers the latest location of device before it is moved.

The definition of basic device status types in PS has some deficiency to achieve the goal of service for contenting user requests. We suggest special space types of LS to reflect user requirements and space circumstances.

- FUSION: When a device status type becomes "OVERLAP", a new space appears as a multiple PS, and this is $LS_i = \{PS_1 \cup \cdots \cup PS_n\}$, $(n \geqslant 2)$. This type makes the service be available in any place where it is required. Even though D_k actually exists in one PS, it can be occupied in others also. If LS_1 has a role of an office, users can be exposed both the 'working' service in PS_2 and the 'printing' service in PS_3 at any position in LS_1.
- SEPARATION: If a device has "MOVED" status type, LS_i is disjointed to two individual spaces; PS_2, PS_3 which were considered as one space LS_1.

C. Device Management Method – Registration/Withdrawal

For analyzing the device movement, we use the 'Registration' and the 'Withdrawal' processes to figure out which device is entered in or out of the service space.

- Registration: If the 'Registration' is occurred, this supposed that D_k inflows a service space and is ready to offer a service operation. After D_k is registered, a system analyses the device status type such as 'NEW', 'MOVED', 'OVERLAP', or 'MOBILE' by device movement histories.
- Withdrawal: When a device moves to other space, it is withdrawn from the registered space. The system notify changes of the space by the 'Withdrawal' of devices

V. Development and Application

A. Design and Development of the Space Manager

We design and create the space manager(SM) to materialize the space model in USS. It gives each device the status type and processes registrations/withdrawals for the management of the space model. We present the block diagram for SM operating parts in Fig.5 and the prototype in Fig.6. Each part is implemented by a human detection sensor, an infrared module, an IEEE 802.15.4 module, a Bluetooth module, and a microprocessor.

B. Experiment in USS

We show the service environment in a general home domain in Fig.7. We assume that the home basically has a living room, a bed room, and a kitchen with many devices represented by D_1~D_7. Since no space model is adapted on it yet, a user is just allowed only the defined services which are limited by the device installation. In the living room, the user cannot reach a certain music service provided by the audio which is in the kitchen. Moreover a service system cannot find where the requested devices are located in its service domain because no device location awareness method is working on it yet. The system remembers only the initial installation settings even though a user brings the device to other place. This fact potentially causes wrong service operations to users often.

To solve the problem, the service environment applied our suggestion is presented in Fig.8. By binding to a certain space manager, devices are participated in the service operation.

- Registration/Withdrawal for the device awareness: When all service suppliers is entered in USS at the beginning, 'Registration' makes each device bound with each SM_1~SM_3. The device's inflow and a user's movement are detected by a human detection sensor.SM transports device communication settings. After this, the status type of the device is defined as "NEW". It is only available its own registered SM without any interruption from the others. As shown in Fig.7, a humidifier is moved from the bed room (the registered space) to the living. It will be ready to operate a service in the new service space when it is registered under SM_1. D_4 has "MOVED" status type in SM_1 and the list of device management in SM_2 is updated that D_4 is N/A (Not Available).
- Sharing by the LS types for offering services: The audio was registered in the kitchen at the first time. Since the "Reading environment service" is requested in the living room, the device should be defined as "OVERLAP" and takes both space IDs of SM_1 and SM_2. By following this, the place where the service by D_7 is settled as "FUSION". This service space is recognized as one LS_1; even it consists with different PS_2, PS_3.

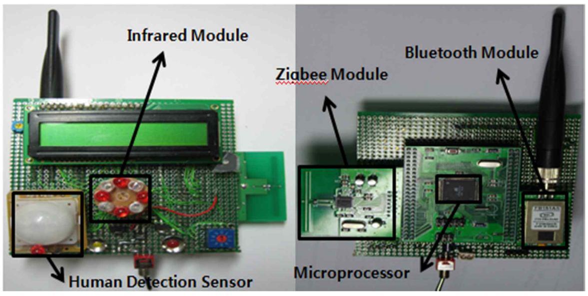

Figure 4. The State-Transition for the Location Awareness of D_k.

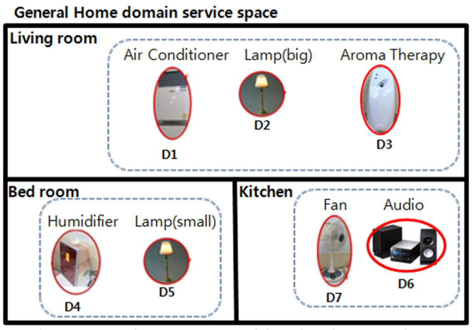

Figure 5. The State-Transition for the Location Awareness of D_k.

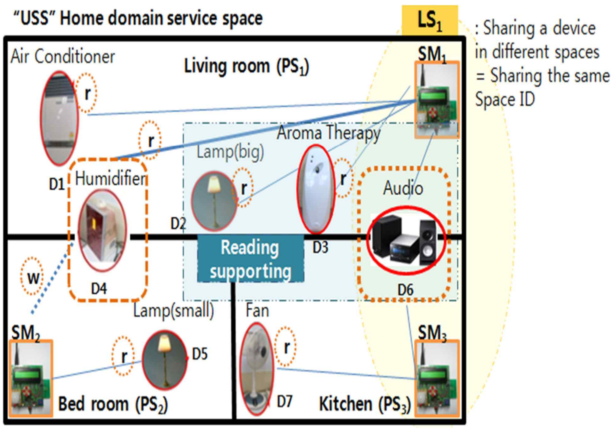

Figure 6. The State-Transition for the Location Awareness of D_k.

VI. Conclusion

The user-customized service is an essential goal of the ubiquitous smart space. Realizing this autonomic service needs the proper method which handles all circumstance information occurred in USS. In this paper, we proposed a model to deal with the space characteristics and the device location. Based on the space model, we defined new space types which reflect characteristics of ubiquitous computing and new device status types which manage device location information. We have developed an embedded system; SM for managing service environments. By the experiment our space model, we can provide intelligent and autonomic services by the ubiquitous computing. In the future, we will establish service policy and information management guideline about devices with users. These aim to make ubiquitous service tightly coupled with users by learning about user preference and usage of service.

Acknowledgment

This research is supported by the ubiquitous computing and networking project (UCN) Project, Knowledge and Economy Frontier R&D Program of the Ministry of Knowledge Economy (MKE) in Korea and a result of subproject UCN 10C2-T3-10M.

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education, Science and Technology(2010-0013796)

References

[1] F. Zhu, M.W. Mutka, and L. M. Ni, "Service discovery in pervasive computing environments. IEEE Pervasive Computing," IEEE Pervasive Computing, vol.4, no.4, pp. 81–90, 2005.

[2] M. Parashar, S. Hariri , Autonomic Computing : Concepts, infrastructure and Applications, CRC Press, 2006.

[3] M. Lee, J. Lee, S. Park, and W. Cho, "SOA-based Service Layering for Facilitating Dynamic Service Composition and Alternative Service Discovery," J. Inf. Sci. Eng 26, vol. 3, pp.991-1010 , 2010.

[4] H. Niwa, K. Kodaka, Y. Sakamoto, M. Otake, S. Kawaguchi, K. Fujii, Y. kanemori, and S. Sugano, "GPS-based Indoor Positioning System with Multi-Channel Pseudolite" IEEE International Conference on Robotics and Automation, , pp. 905–910, 2008.

[5] H. Kim, J. Choi, "Advanced indoor localization using ultrasonic sensor and digital compass", International Conference on Control, Automation and Systems, pp. 223–226, 2008.

[6] T. Hori, Y. Nishida, "Improvement of Position Estimation of the 3D Tag System," 17th IEEE International Symposium on Robot and Human Interactive Communication, pp. 436–441, 2008.

[7] M. Sugano, T.Kawazoe, Y. Ohta, and M. Murata , "Indoor localization system using RSSI measurement of wireless sensor network based on zigbee standard," The IASTED International Conference on Wireless Sensor Networks, 2006.

[8] J. King, R. Bose, H.I. Yang, S. Pickles, and A. Helal, "Atlas: A Service-Oriented Sensor Platform", Local Computer Networks, Proc.31st IEEE Conference on, pp.630-638, Nov 2006.

[9] Y.A Malkani, L.D. Dhomeja, "Location Aware Device Discovery for Physically Contains Environmets", Computer, Control and Communication, 2nd International Conference on, pp. 1–5, Feb 2009.

[10] Y.M Cheng, "Using ZigBee and Room-Based Location Technology to Constructing an Indoor Location-Based Service Platform", Intelligent Information Hiding and Multimedia Signal Processing, 2009. 5th International Conference on, Sept 2009.

[11] Whole Building Design Guide a program of the National Institute of Building Science, http://www.wbdg.org/

[12] E. Choi, C. Bak, S. Kim, and J. Lee, "Development of a Space Manager for Ubiquitous Smart Space", 36th Korea Computer Congress, , vol.36, no.1, pp.256-261 , 2009.

[13] E. Choi, C. Bak, S. Kim, and J. Lee, "Space Model for Managing Ubiquitous Smart Device" Proc. IEEE Symp. Computational Intelligence in Scheduling (SCIS 07), 36th Korea Computer Congress, vol.36, no 2, pp.345-350, 2009.