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Action Research on Development and Application of Internet of Things Services in Hospital

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Objectives: Services based on the Internet of Things (IoT) technologies have emerged in various business environments. To enhance health service quality and maximize benefits, this study applied an IoT technology based on NFC and iBeacon as an omni-channel service for patient care in hospitals. **Methods:** Application of the IoT technology based on NFC and iBeacon was conducted in a general hospital during August 2015 through June 2016, and the development and evaluation results were aligned to an action research framework. The five phases in the action research included diagnosing, planning action, taking action, evaluating action, and specifying learning phases. **Results:** During the first two phases, problems of functional operations in a hospital were diagnosed and eight service models were designed by using iBeacon and NFC to solve the problems. Service models were applied to the hospital by installing beacons, wearable beacons, beacon scanners, and NFC tags during the third phase. During the fourth and fifth phases, the roles and benefits of stakeholders participating in the service models were evaluated, and issues and knowledge of the whole application process were derived and summarized from technological, economic, social and legal perspectives, respectively. **Conclusions:** From an action research perspective, IoT-based healthcare services were developed and verified. IoT-based services enable the hospital to acquire lifelog data for precision medicine and ultimately be able to go one step closer to precision medical care. The derived service models could provide patients more enhanced healthcare services and improve the work efficiency and effectiveness of the hospital.

Keywords: Internet, Wireless Technology, Hospital Communication Systems, Telemedicine, Computer Communication Networks

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I. Introduction

The health paradigm has changed from cure-based to care-based services [1]. Since the advent of new technologies such as near-field communication (NFC) and iBeacon, healthcare services have been combined with Internet of Things (IoT) technologies. In the healthcare sector, Brigham and Women's Hospital in the Unites States and the Client Home Healthcare system of the National Statistical Office of the Netherlands are good illustrations of system buildup based on IoT. As a case of convergence of NFC and healthcare services, the NFC system developed at Brigham and Women's Hospital allows nurses to keep track of medications safely for patients [2]. Statistics Netherlands announced that the population of persons aged 65 years and older in the Netherlands will increase from 15.6% in the latter half of 2010 to 25.6% in 2040. Accordingly, the government launched the NFC Home Healthcare Service as part of a wider effort to address the needs of the elderly [3]. It focused on enabling the elderly aged 65 years and above to live independently. This service automates information, such as patients' arrival time, retention time, and healthcare services provided at home, which used to be written by hand.

The Home Healthcare System differs from other healthcare systems by enabling healthcare service providers to register information on their patients' health and healthcare services, and making it easy to identify the location of the healthcare service provider, which is helpful in planning manpower allocation and adjusting patient management schedules. By applying new information technology (IT), hospitals are able to enhance healthcare quality, work flow, and patient safety [4-6].

In designing healthcare systems to simplify and automate the work process of hospitals, generally NFC has been applied [2,3]. Recently, beacon technology has been emerging as a novel approach for many types of businesses that provide contextual information based on the proximity of users and the prevalence of smartphones [7]. It is a low-cost hardware that transmits a short burst of data over a near distance using the Bluetooth low energy (BLE) protocol. This data contains basic text information that could include a URL and other relevant information.

IoT refers to appliances, objects, and other things that are enabled by access to the Internet [7]. iBeacon and NFC are considered as technologies for IoT [7,8]. Services based on IoT technologies have emerged in various business environments. These services link offline and online shops to maximize customers' offline shopping experience and satisfy the needs of consumers in their purchase routes [9-15].

Based on these technologies, this research applied NFC and iBeacon to provide patient care as an omni-channel service for hospitals. Explicitly, this study attempted to answer the following two questions to build various healthcare service models and develops a new system: (1) How hospitals apply new information technologies such as NFC and iBeacon to patient care services and (2) What are the benefits and disadvantages of the NFC and iBeacon-based service model adopted in hospitals.

II. Methods

An application of an IoT technology based on NFC and iBeacon was conducted in a general hospital in Seoul, Korea during August 2015 through June 2016, and the development and evaluation results were aligned to action research framework. Action research is directly involved in planned organizational change. The action researcher intervenes by creating organizational change and simultaneously studies the impact of this change [16]. Baskerville and Wood-Harper [17] suggested that action research was ideal as a systems development methodology for information systems research. We adopted a five-phase, cyclical process, which can be described as an ideal exemplar of the original formulation of action research [18] to development of a patient care service using beacon and smart tag system supported by a government grant for IoT business.

Figure 1 shows the five phases of the research process. During the diagnosis phase, we identified the primary problems that are the underlying causes of the hospital's desire for change. Current problems in the hospital were identified after regular meetings with eight departments: Psychiatry, the Cancer Center, Surgery, the Nutrition Team, Physical Medicine and Rehabilitation, the General Affairs Team, the Facility Management Team, and Nursing. During the action planning phase, we specified actions that the hospital could take to relieve or improve the primary problems identified in the diagnosis phase. Then, our research team conducted interviews with the hospital healthcare practitioners and observed the practitioner's situation.

At the action taking phase, we collaborated in active intervention with stakeholders. With reference to the "patient care service based on beacons and smart tags," a new form of patient care service can be carried out when a patient confirms a signal sent from a BLE beacon to his/her portable terminal (hereinafter the confirmation process of the BLE beacon signal is referred to as 'catch'), or NFC tags distributed in the hospital are read by the patient's portable terminal (hereinafter the NFC tag reading process is referred to as 'touch'). This smart service enables the hospital to have

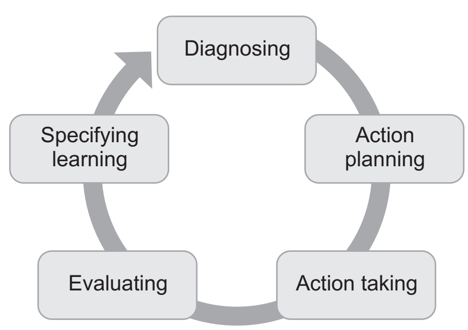

Figure 1. Action study framework.

continued relationships with patients even after they leave a certain area of the hospital.

At the evaluating phase, the collaborative researchers and practitioners determined whether the theoretical effects of the action were realized, and whether these effects relieved the problems. Timmers [19] explained that a business model is architecture for the product, service, and information flow, including a description of the various business actors and their roles; a description of the potential benefits for the various business actors; and a description of the sources of revenues. According to a definition by Timmers [19], we evaluated the business model of the hospital that focused on the IoT (NFC and iBeacon)-based medical service areas. At the last phase, specifying learning phase, we gained a better understanding of the issues and knowledge through interviews with healthcare practitioners [20].

III. Results

1. Diagnosing Phase

By interviewing with patients and healthcare practitioners, difficulties and problems in current functional operations in hospital were identified in the diagnosing phase. From both patient and medical team perspectives, problems were listed in eight service functional areas, as shown in Table 1.

2. Planning Action Phase

During the planning action phase, our research team planned appropriate actions for ameliorating the difficulties and problems identified in the diagnosing phase. As a result, eight service models were proposed to improve work efficiency and quality of healthcare services, as shown in the last column of Table 1. The first four service models were focused on work process automation of the hospital to make it easy to edit the contents that are provided to patients and to share the results with other medical staff online. The remain-

Table 1. Analysis of current functional operations in a hospital

Service function	Problems on patient side	Problems on medical team side	Service model
Participation in recovery program	Difficult individual tour	Inconsistent business process to give information on healing program to participants	Healing tour
Information provision and education	Difficulty to acquire information and knowledge	Business process creating contents on a paper form Difficulty to share information with patients because of analogue contents	Cancer information/ education
Evaluation of healthcare services	-	Complex business process to make service survey paper, scoring service and distribute results to the team	Survey
Diagnosis of psychological anxiety	Difficulty of self-diagnosis and tracking the results	Complex business process to make NCC psychological assessment form and distribute the result to medical team Difficulty to track the result	NCC psychological assessment
Guidance of location	Difficulty to detect location	Interrupting by patients asking the location	Indoor navigation
Prescription of exercise	Difficulty to gain information about exercise volume	Difficulty to check whether patients exercise or not, measure the effect of kinesiatrics	Exercise volume check
Regular check-up of inpatients	-	Difficulty to find out patients who are in emergencies in blind spots	Monitoring high-risk inpatients
Verification of patient medical information	-	Difficulty to immediately gain patient's information and to give first aid without delay	Delivering real-time medical information of inpatients on emergency

NCC: National Cancer Center.

ing four service models were planned to enhance the quality of healthcare services by providing innovative services to patients and medical staff. Through implementation of the system based on a wearable beacon (necklace form) sending signals to a beacon scanner and a portable terminal with the patient receiving beacon signals, the medical team and patients were able to obtain information in real time. This facilitated more prompt treatment and convenient services resulting in better service outcomes with efficient and effective care.

3. Taking Action Phase

1) System architecture

Patient care service based on beacons and smart tags is composed of beacons and NFC tags installed in a hospital, 'user applications' used by users through their portable terminal, a 'wearable beacon' worn by users, a 'beacon scanner' that checks signals from beacons owned by users, a 'service management system' for easy management of beacons and tags and efficient service provision, and a 'service provision server and engine' for the provision of various services. Service models are classified into two types depending on the service structure. In a user-reader service system, including service models 1 through 6, a user's portable terminal serves as a beacon reader. On the other hand, in a user-tag service system, including service models 7 and 8, a wearable beacon with the patient sends signals to beacon scanner.

The procedure of the user-reader service is as follows (see Figure 2). A user performs beacon catch and tag touch functions through his portable terminal (①), and the user's portable terminal receives various data values including ID and URL through the beacon catch or tag touch (②). Then, the user requests the service management system for a service suitable for his condition through his portable terminal, and ID (URL) and user ID are delivered together in this process (③). The service management system sends the beacon/tag ID and user ID delivered from the user to the beacon/tag database (DB) and user DB, and receives corresponding information (④-1 through ⑤-2) and verifies the service requested by the user and whether he/she has the authorization for its use through the beacon/tag information and user information (⑥). When the user's authorization for use of service is confirmed, the service is requested from the service provision server and engine (⑦), the service provision server and engine create service contents (⑧), and they deliver the service to the user (⑩) through the service man-

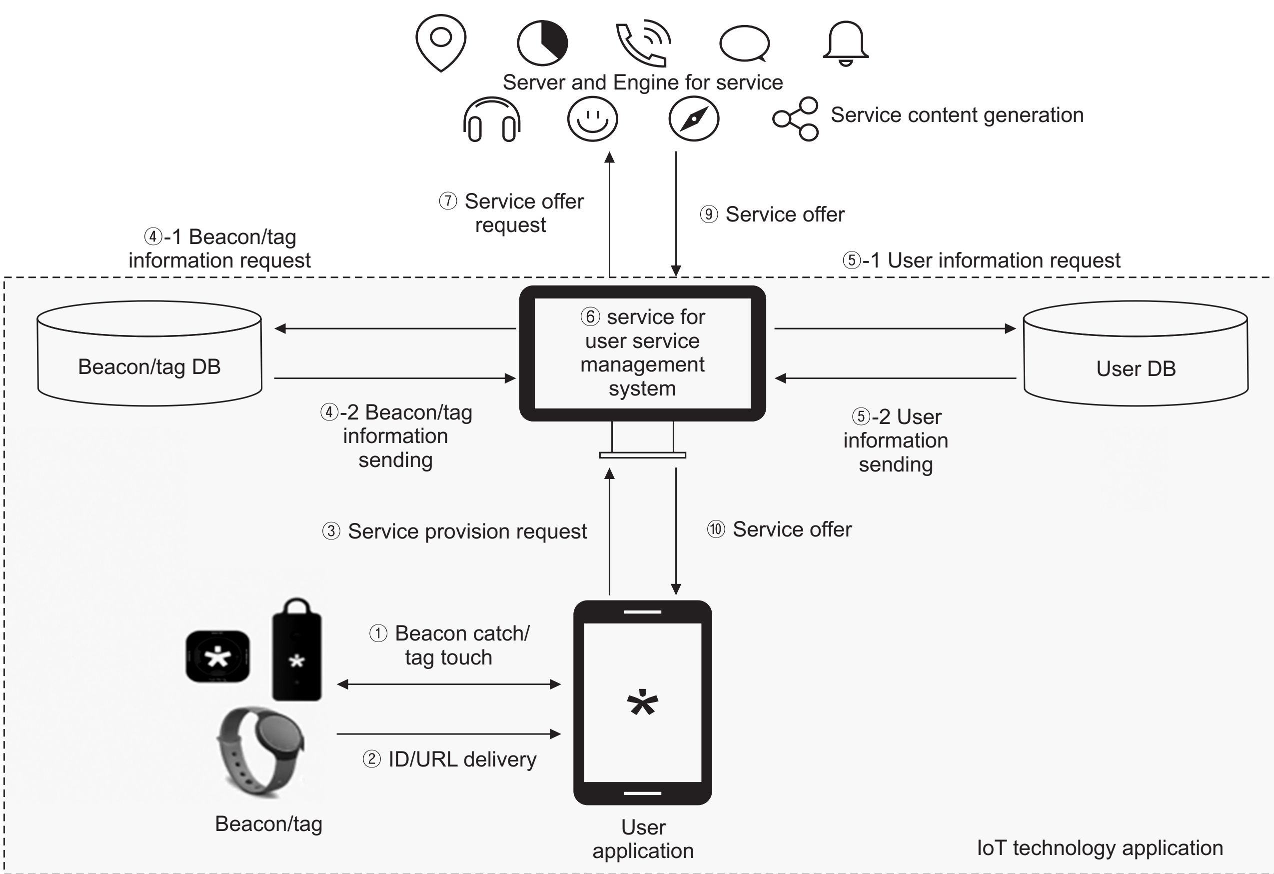

Figure 2. User-reader service system.

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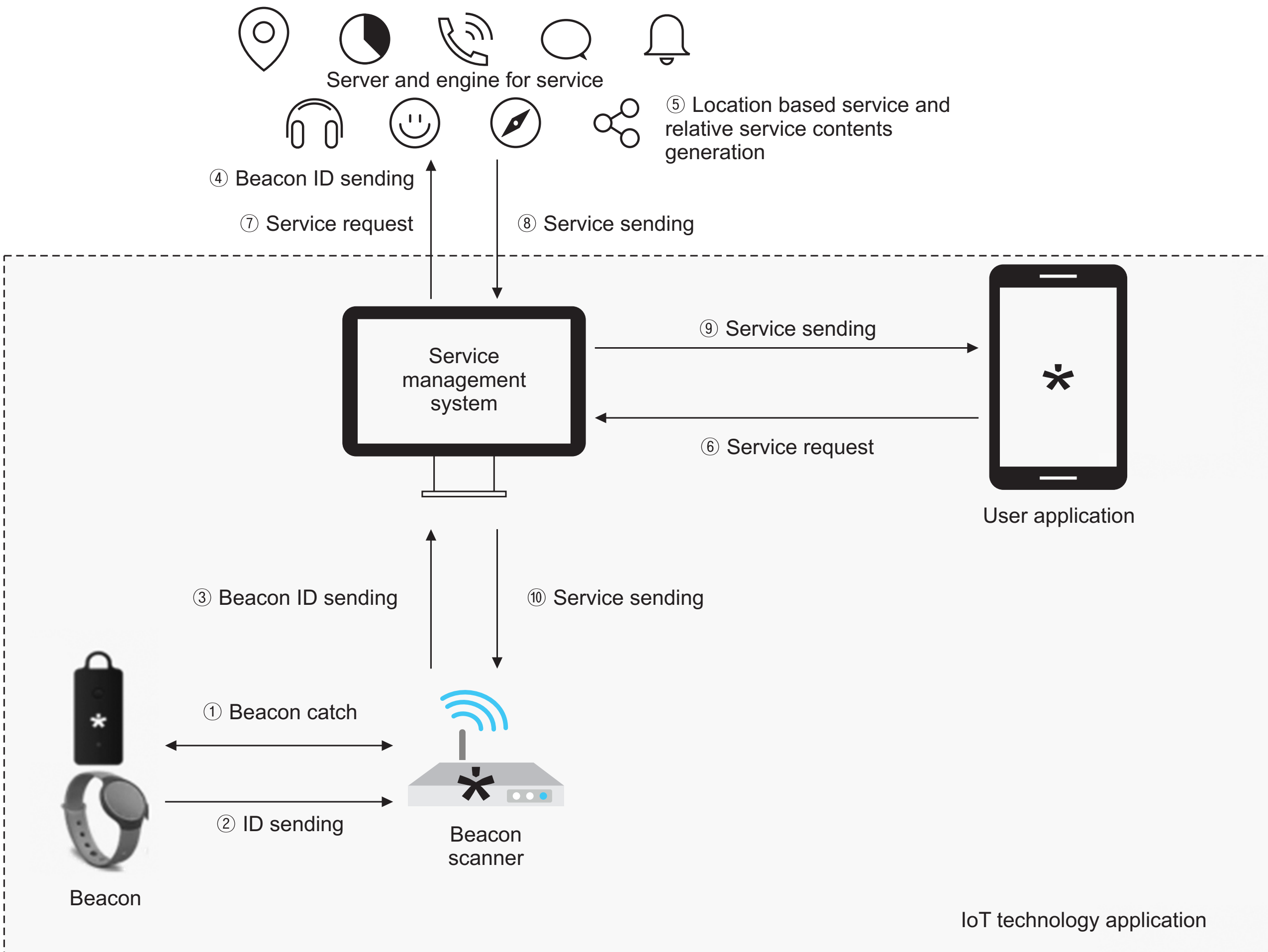

Figure 3. User-tag service system.

Figure 4. User interface of application for patients.

agement system (⑨).

The procedures of user-tag service are as follows (see Figure 3). A beacon scanner performs the beacon catch (①) and receives various data values, including the beacon ID, through the beacon catch (②). A beacon scanner delivers the beacon ID to the service management system (③), which delivers the beacon ID to the service provision server and engine according to the set process (④). Then, the service provision server and engine create service contents such as patient location positioning and asset location positioning through the location awareness module (⑤). A user requests the service management system for a service, which verifies whether the user is authorized, and sends the request to the service provision server and engine (⑥, ⑦). As the final step, service provision server and engine deliver the requested service to the user through the service management system, and in the case of the user-tag service, a push type service is provided to a user according to the service characteristics (⑧, ⑨).

2) User interface of application and web service

Our research team suggested user interface with hospitals and hospital practitioners to reflect opinion of users. Figure 4 depicts user interface of six services for patients. The services include healing tour, cancer information/education, survey, NCC (National Cancer Center) psychological assessment [21], indoor navigation, and exercise volume check.

User interfaces of app and web services for medical team are shown in Figure 5. The application services for medical team include log-in service, emergency call, patient information service, NCC result history, and exercise result history.

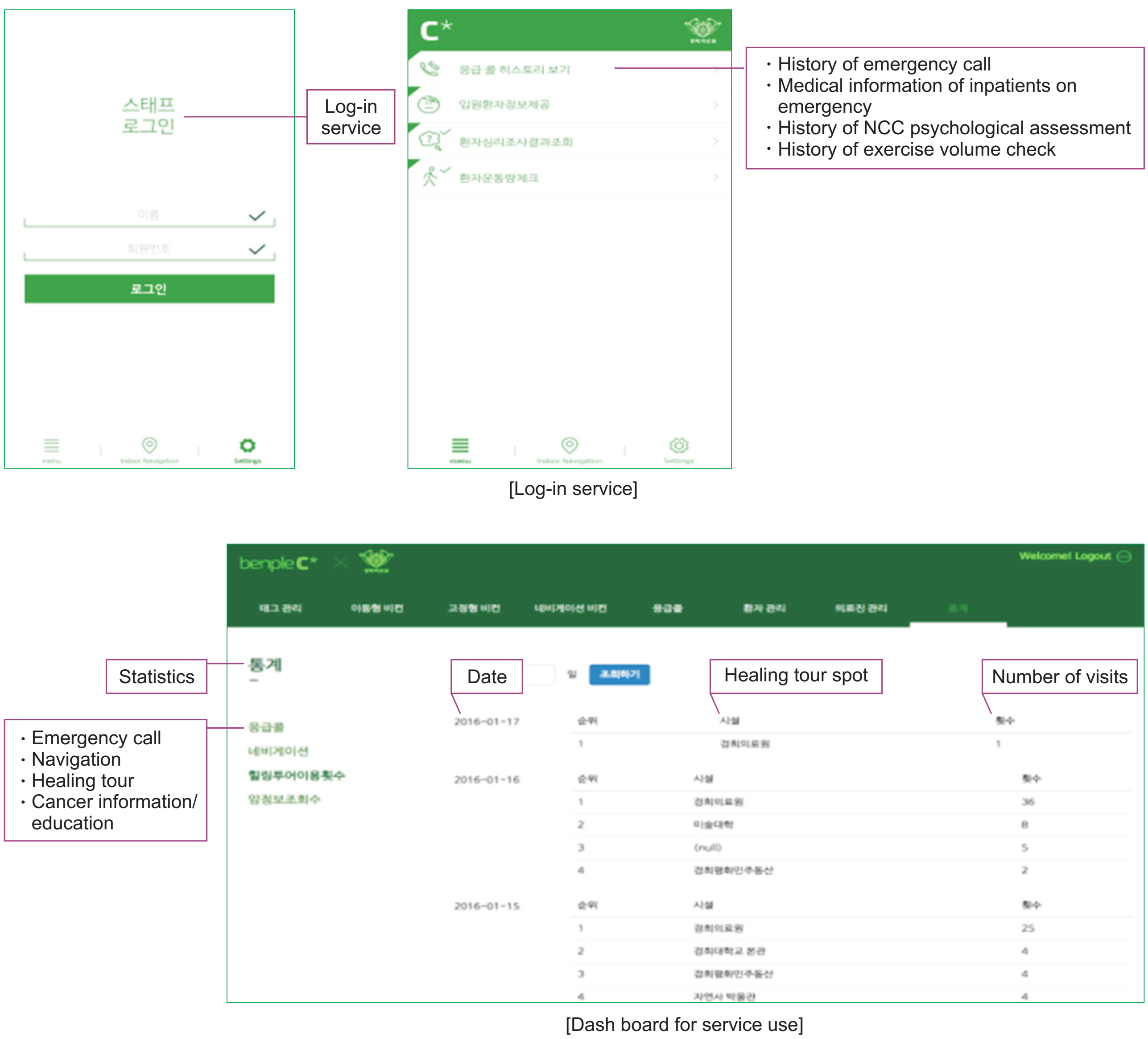

Figure 5. User interface of application and web for medical team.

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Figure 6. Installation of hardwares. (A) Outdoor beacon, (B) indoor beacon, (C) beacon scanner, and (D) NFC tag and wearable beacon.

And, web services for medical team provide various functions such as beacon and tag management service, medical team and patient management service, and dash board for service use.

After software was developed, hardwares such as indoor beacon, outdoor beacon, wearable beacon, beacon scanner, and NFC were installed. Figure 6 presents partial installation of various hardwares.

4. Evaluation Phase

The evaluation business models of the hospital were based on the definition by Timmers [19] using architecture for product, service, and information flow presented in Figures 2 and 3. Participants of the NFC/iBeacon-based medical service model were classified as inpatients, outpatients, hospital, and NFC/iBeacon-based service provider, and the roles and potential benefits for each participant are proposed, as described in Table 2.

5. Specifying Learning Phase

As the last stage of one loop of action research, the derived issues and knowledge on the process of developing and applying NFC and iBeacon were summarized from technological, economic, social, and legal perspectives, respectively (see Table 3).

IV. Discussion

The current challenges faced in the healthcare sector that often lead to healthcare operation failures include medical mistakes, increasing costs, theft loss, drug counterfeiting, and inefficient workflow. To deal with automated care, improved work procedures, guided indoor pathways, automatic data capturing, and collaboration, these problems can be overcome by appropriate IT supports such as radio-frequency identification (RFID). In particular, RFID technologies have been applied to tracking and tracing patients, integrated data management systems, efficient data capturing mechanisms, and human error prevention processes [22-26].

In our action research, we applied and verified the IoT technology (NFC and iBeacon)-based service models for the healthcare sector. In contrast to previous studies, which mainly applied NFC, we applied not only NFC but also iBeacon technology. The proposed services with emerging IoT technology, such as iBeacon and NFC, are effective to solve the aforementioned problems. Each service model produced good results, but there are some issues that arise with the adoption of iBeacon and NFC in various application areas. Previous studies have reported similar service models for vulnerable patients that can improve care [27-30].

The former six service models adopted beacon technol-

Table 2. Roles and improved benefits of stakeholders

Participants	Roles	Improved benefits
Inpatients	Download service application Use various services (survey, NCC psychological assessment, cancer information education, exercise amount check, patient monitoring, delivering real-time medical information)	Gain valuable medical information and data Improve accessibility to the hospital and doctors Reduce recovery time Increase life maintenance possibility by shortening first-aid response time
Outpatients	Download service application Use various services (healing tour, cancer information education, NCC psychological assessment, indoor navigation)	Easy to identify and manage one's own psychological state Gain beneficial information Easy to find treatment location Participate on program for recovering from cancer treatment
Hospital	Prepare necessary infrastructure such as NFC tags and beacons Provide wearable beacons to high-risk inpatients and register the beacons Upload cancer information education, survey, NCC psychological assessment contents on IoT service system Use app/web services for the medical staff for patient management	Enable the hospital to maintain relationships with patients Easy to manage patients Increase the turnover ratio of patient rooms by reducing patients' recovery time Reduce first-aid response time via identifying the location of an emergency patient Enable first-aid at a suitable time and place via gaining real-time medical information of patients on emergency Reduce medical error by misidentification Enhance the effectiveness of marketing of the hospital's healing programs Improve the brand awareness of the hospital Improve quality of healthcare via acquiring patients' data Improve work efficiency
Service providers	Develop a service model and system Build and maintain service infrastructure	Service fee from hospital

ogy to automate the current work process, which is time consuming and error prone. It increases work efficiency and helps fast recovery of inpatients. The latter two service models provide patient information, such as name, date of birth, allergy, surgical site, etc., to the medical team, increase patient safety, and shorten the time required to check patient information in case of an emergency. In summary, our findings extend the exising knowledge of previous studies.

In addition, new services using beacon technology, such as indoor navigation, exercise volume checking, monitoring of high-risk patients, and real-time information delivery of emergency patients, can improve the competitiveness of hospitals. NFC and beacon-based services, which are near-field wireless communication technologies, were developed and applied during four months, which is a relatively short period of time in comparison to existing information systems.

Another feature is the mobile-based healthcare system, in which most of the patients and medical staff have smartphones and are skillful at using them. Therefore, it is cost saving because patients and medical staff do not need expensive equipment (e.g., beacon reader). Currently, changes in healthcare services in the near future are being discussed. A new medical approach, called 'precision medicine', is being developed for the prevention and treatment of diseases, considering differences among people's genes, environment, and lifestyle. IoT-based services enable a hospital to acquire lifelog data for precision medicine and ultimately be able to move one step closer to precision medical care.

The present study has several theoretical and practical implications. From an action research perspective, IoT-based healthcare services were developed and verified. We applied the concept of omni-channel service to the medical field, which has been mainly implemented in other fields to maximize customer experience, increase satisfaction and increase offline sales. The new type of omni-channel medical service proposed in this study is provided to outpatients even after

Table 3. Issues and knowledge through service development and application

Aspect	Issues and knowledge
Technical	Beacon: diffused reflection of signals due to a number of beacon → beacon re-arrangement to reduce diffused reflection
	Beacon scanner: system down due to beacon signals → software update adding filtering function
	Wearable beacon: infection concerns → decision on use as a disposable device
Economic	Expensive beacon scanner installation cost: cost for network connection to link beacon scanner with server
Social and legal	Outdoor beacon: (1) frequent loss by difficulty to adhere to uneven and dusty surface for healing tour service → resetting with high-strength adhesive; (2) loss by keeper → delivering official document on IoT medical service
	NFC and beacon: inexperience and unskilled patients and medical team → sharing service introduction video and service manual book (e.g., guideline initial setup for NFC and app use), periodic education
	Support of medical team: a strong will to persuade the patients to use service and wear a beacon → organizing cooperative team and periodic meeting/interview with researcher

the patient leaves the hospital, and the information is managed in real time by sharing it with the medical staff. In addition, it is possible for patients to experience unprecedented medical services in the hospital space and to share such experience online in real time; thus, the satisfaction of medical service is improved by providing seamless medical service by extending the space.

From a practical perspective, the NFC and beacon-based IoT system generates additional patient-related data that the hospital could not obtain in the past, such as the location of the patient (from monitoring service for high-risk inpatients, patient exercise volume check service), frequency of service usage per spot or contents (from healing tour service, indoor navigation service, cancer information/education service), and service channel preference (number of shares per social media channel). By analyzing the location data, it is possible to identify blind spots of the hospital and minimize patients' movement between hospital rooms. Also, by analyzing lifelog data, such as patient exercise data, personalized treatment can be performed. In conclusion, it is expected that hospital optimization will be possible by improving work processes and services through data analysis.

However, this study is limited to a service period and service adoption in one specific and tertiary hospital. Thus, the benefits of the IoT-based service model in other hospitals, such as secondary and primary hospitals, need to be examined to verify the findings of this study. Thus, the result findings should be interpreted with caution. Additionally, considering the time it takes for relevant hospital employees to form a habit of using a new service, we expect an increase in productivity and sales from 2017. Therefore, further research also needs to be conducted on service satisfaction and economic evaluation.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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