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An extended three-dimensional Geofence platform with rule-based context-awareness service for the internet of things

Young-Keun Choi*, Sungkuk Cho, Sungkon Park**,**
Young-Hyun Eom*, Inhwan Kim***, Byungkook Jeon*****
[*]*Dept. of Computer Science, Kwangwoon University, Nowon-gu, Seoul 01897, South Korea*
[**]*Dept. of Multimedia Eng., Gangneung-Wonju Nat'l. University, Wonju-city 26403, South Korea*
[***] *Dept. of Computer Science, Gangneung-Wonju Nat'l. University, Wonju-city 26403, South Korea*

Abstract: Even though more than 30 billion devices are to be wirelessly connected to the Internet of Things(IoT) by 2020, a considerable number of things to be subjected to the IoT are currently not equipped with a wired/wireless network interface. To solve this problem, we propose an extended three-dimensional(3D) geofence platform with rule-based context-awareness service to provide the IoT. This includes indoor context-awareness as well as two-dimensional(2D) location information. The proposed platform consists of 3 components such as a context-aware component, the 'thing' of the IoT, and a 3D geofence app based on the 3D geofence framework as the result of our preliminary studies. To implement rule-based context-awareness service, the proposed platform adopts and simulates multiple elevators as a rule model, since each elevator is similar to a vertically moving vehicle, consumes large amounts of power, and also many elevators themselves do not currently support wireless networks. Therefore, the proposed platform is feasible not only to process rule-based context-awareness service but also to save power and to improve the operating efficiency of multiple elevators.

Keywords: Three-Dimensional Geofence, Rule-based Computing, Context-Awareness, Elevator, Internet of Things

1. Introduction

According to Gartner in 2014, there will be nearly 26 billion devices on the Internet of Things(IoT) by 2020[1]. Also, according to ABI Research, more than 30 billion devices will be wirelessly connected to the IoT(or IoE, Internet of Everything) by 2020[2]. In a recent survey and study carried out by the Pew Research Internet Project, a large majority(83%) of the technology experts and engaged Internet users who responded agreed with the notion that the Internet/Cloud of Things, including embedded and wearable computing(and the corresponding dynamic systems[3]), will have widespread and beneficial effects by 2025[4]. As such, it is clear that the IoT will result in a very large number of devices being connected to the Internet[5]. In an active move to accommodate new and emerging technological innovation, the UK Government, in their 2015 budget, allocated £40,000,000 towards research into the IoT[6].

On the other hand, the IoT envisions an era where billions of sensors are connected to the Internet, which means it is not feasible to process all the data collected by those sensors. Therefore, context-awareness will play a critical role in deciding which data needs to be processed, and much more[6,7].

Context-awareness computing and service evolved from desktop applications, through mobile computing, web applications, ubiquitous and pervasive computing, and ultimately to the IoT, over the past decade[6,7]. Context-awareness computing and service has played an important role in tackling the big-data challenge in previous paradigms, such as mobile and pervasive, which lead us to believe that it will continue to be successful in the IoT paradigm as well. Context-awareness computing and service allows us to store context information linked to sensor data, so the interpretation can be done easily and more meaningfully. In addition, understanding context makes it easier to perform machine-to-machine(M2M) communication, which is a core element in the IoT vision[7].

Geofencing is a promising application that will become possible when the IoT becomes organized and connected by location[8-19]. A geofence, as a subset of location-based services(LBS) or a small-scale LBS, is a virtual perimeter for a real-world geographic area, which could be static or dynamic[8-14]. It has the necessary properties to provide context-awareness, such as location awareness and sensing[8-11]. Conventional geofencing applications incorporate one of two-dimensional(2D) maps(e.g., Google Maps, Bing Maps, Yahoo Maps, Daum Maps, and Naver Maps), allowing administrators to define boundaries on top of a satellite view of a specific geographical area[13-19]. However, these applications do not provide three-dimensional(3D) spatial information, regardless of whether they are used indoors or outdoors.

Therefore, in this paper, we propose an extended 3D geofence platform with rule-based context-aware computing and service to support the IoT, which includes indoors context-awareness as well as 2D location information. The proposed platform consists of 3 components such as a context-aware component, the 'things' of the IoT, and a 3D geofence app based on the existing 3D geofence framework. Basically, the existing 3D geofence framework as a result of our preliminary studies supports the automatic activation or deactivation of the specified 3D geofence using the temporal property, and can recognize and determine whether a user is in indoors or outdoors[8-15]. In order to implement rule-based context-awareness service with the proposed platform, we consider a rule-based IoT model assuming scenarios for the IoT. The rule-based model adopts multiple elevators as the 'thing' of the IoT, since most of elevators currently have no wireless network interface, consume large amounts of power, have their own automatic operating system, and so on. Therefore, even if elevators have no wireless network interface, the proposed platform can not only be processing rule-based context-awareness service for the IoT but also saving power and improving the operating efficiency of multiple elevators.

In near future, according to the IoT technology, we should expect the smart things such as the smart-car, smart-ship, smart-home, smart-building, smart-farm. The proposed 3D geofence platform will be a valuable application for the IoT with LBS.

The paper begins with a review of related work, then goes on to describe an architecture of the proposed platform, before providing results from an early user study, followed by a discussion and conclusion.

2. Related Works

During the past decade, the IoT has gained significant attention in academia as well as industry[1-7]. The main reasons behind this interest are the capabilities that the IoT will offer[20,21]. It promises

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to create a world where all the objects(also called smart objects[22]) around us are connected to the Internet and communicate with each other with minimum human intervention[23]. The ultimate goal is to create 'a better world for human beings', where objects around us know what we like, what we want and what we need, and act accordingly without explicit instructions[24]. Context-awareness computing has played an important role in tackling the big-data challenge such as mobile, pervasive, ubiquitous, which leads us to believe that it will continue to be successful in the IoT paradigm as well. Context-awareness, as a core feature of pervasive and ubiquitous computing systems, has existed and been employed since the early 1990s[5-7].

Also, LBS are used in a variety of contexts, such as personal life, public/private work, entertainment, health and business[8-19,25]. In particular, the concept of geofence appears ubiquitously in discussions of LBS, with a special focus on its use in retailing[8-12,14,18].

Geofencing could be used to generate individual Points of Interest(PoIs) as well as an area within a specified radius such as around a store. In addition, a geofence could be a predefined set of boundaries such as school attendance zones or neighborhood boundaries. Custom-digitized geofences are also in use. When the location-awareness device of a user enters or exits an area defined by a geofence, the device receives a generated notification, which might contain information about the location of the device[10,13]. However, the conventional geofences does not provide 3D location information, regardless of whether it is used indoors or outdoors[8-18].

Many geofencing applications incorporate Google Maps, allowing administrators to define boundaries on top of a satellite view of a specific geographical area[15-19]. Other applications define boundaries by using the longitude and latitude, or through user-created and web-based maps. Recently, some web-based maps such as Google Maps and Naver Maps have provided indoor map services for some specific buildings or subway stations, as shown in Figure 1[19].

Figure. 1. Google's outdoor and indoor maps of a specific location(e.g. Time Warner Center in NewYork) on smartphone

Examples of geofencing usage are retail marketing, law enforcement, human resource management, compliance management, mobile device management, asset management, and fleet management[25]. Apart from this, Google Playstore and Apple Appstore both offer a number of apps that implement geofencing, such as the leaflets service of the OKCashBag app or the coupon services of the Syrub app[26,27]. While these 2D geofence models do not support indoors location awareness and are stationary, the 3D geofence model as the results of our preliminary studies is an enhanced model that supports indoors location awareness and some various facilities such as dynamicity, temporary properties, flexibility, floatability as well as the attributes of the 2D geofence models[8-15].

Since ThyssenKrupp claim to bring the elevator into the IoT, our target model in this paper assumes multiple elevators as the ‘things’. ThyssenKrupp are taking the data from the elevator controller and storing it on the cloud, analyzing and interpreting it, and applying machine-learning techniques to it[28]. So, the reasons that we chose the elevator as a ‘thing’ of the IoT are as follows. Firstly, an elevator is similar to a car. However, while generally the car is a means of horizontal transportation, the elevator has a similar property but as a means of automatic vertical transportation. Secondly, the elevator operates itself through self-control and operational logic, as would an autonomous car. Thirdly, in a case of multiple elevators, each elevator is operated independently, or in a mutually cooperative way, by the remote monitoring and management system(RMS). Finally, although most elevators themselves do not provide wireless communication services(e.g. WiFi, Zigbee, BLE Beacon, etc.), the RMS manages operational information via a wired network according to the elevator’s control protocol.

3. The extended 3D geofence platform

3.1. An architecture design of the proposed platform

In this section, we design an architecture for an extended 3D geofence platform with rule-based context-awareness service based on the 3D dimensional geofence framework that can determine whether a user is in indoors or outdoors location. The architecture of the proposed platform supports rule-based context-awareness service and computing.

Figure 2 shows the overall platform structure to handle context-awareness service. The structure of the proposed platform consists of 3 components based on the existing 3D geofence framework - Context-awareness Component, the ‘Things’ of the IoT, and a 3D geofence app on smartphone[8-14]. Here, the 3D geofence framework among these components refers to our previous researches and the detailed descriptions of the remainders are as follows.

- Context-awareness Component

  The hierarchical component to support context-awareness consists of 6 modules, as follows:

  - Context Manager – A centralized server managing a blackboard, which stores context information to the Context-aware Database and provides the information to the user’s app and the ‘things’.
  - Context Recognition – Recognizing the situation applied to the ‘things’.
  - Change Sensing – Sensing and processing contexts associated according to the

changes of user's behavior.

- Event Handler – Handling for user's and the things' events sensed by the change-sensing module.
- Rule Analyzer – Analyzing whether the sensed events are suitable for the previously specified rule conditions
- Inference Engine – Applying the following presented rule for information transited through the event-handler module.

- Context-awareness Database - Managed by the Context Manager
- Geofence Database - A database for managing 3D geofence information, e.g. geofence radius, latitude/ longitude, indoor/outdoor location, timestamps of PoIs.

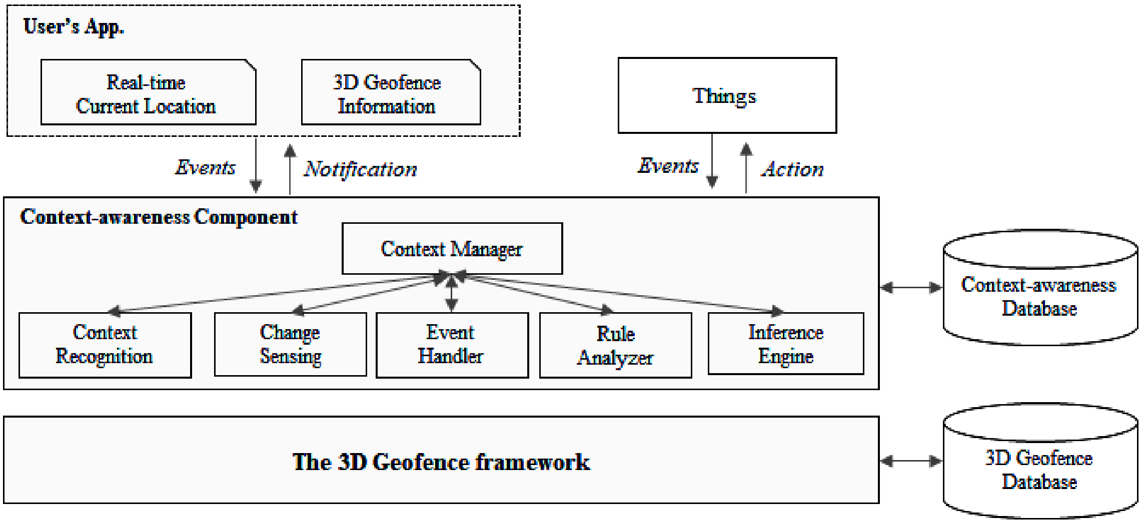

Figure. 2. The overall architecture of the extended 3D geofence platform

3.2 A rule model for the IoT

Geofencing has the basic properties needed to provide context-awareness such as location awareness[10]. Context-awareness computing uses the Event-Condition-Action(ECA) approach as a well-known method[29]. So we propose an extended ECRA that adds rules to the ECA. If a geofence is set up, the geofence platform also complies with the extended ECRA approach based on rules for the geofencing service.

- Event – Entering or exiting the geofencing service zone
- Condition – Sensing and tracking whether entering or leaving the zone
- Rule - Verifying compliance with pre-specified conditions
- Action – Notifying or delivering to user for a variety of services such as alarms, alerts, discount coupons, leaflets.

As a rule model for simulating context-awareness computing for the IoT by the proposed platform, we assume that at least two or more elevators are being operated in a building, and that the proposed

3D geofence platform is set up around those elevators. That is, when a user with smartphone approaches the elevators to ride one of them, the rule is that the geofence automatically chooses and presses one of the up/down-buttons to call an elevator as soon as this situation is detected. However, in this case, the button to be pressed should be chosen to call one of elevators at the floor nearest to the user's location.

Therefore multiple elevators are the thing as a target of context-awareness for the IoT. Knowing that a user is going to reach the elevator in order to ride it is to sense the user's behavior. Choosing which button is pressed is to recognize the user's location and intention.

Figure 3 shows an activity diagram for cooperation by the proposed 3D geofence platform to handle context-awareness service in such situations. Since a **prerequisite of** the rule is the indoor context of the building, the user's smartphone cannot receive the GPS sensor data. Thus, in order to identify the user's indoor location, the proposed platform already adopts the Access Point Grouping Context(APGC) algorithm as the result of our previous research[8-13]. The APGC algorithm identifies the location information on the 3D geofence regardless of whether a user is in indoors or outdoors, or in an interlayer of a building. It does this using only GPS sensors and WiFi Received Signal Strength Indication(RSSI). If the WiFi RSSI values in the algorithm are seen to change, the geofence system recognizes the situation as one where the user goes to the elevator.

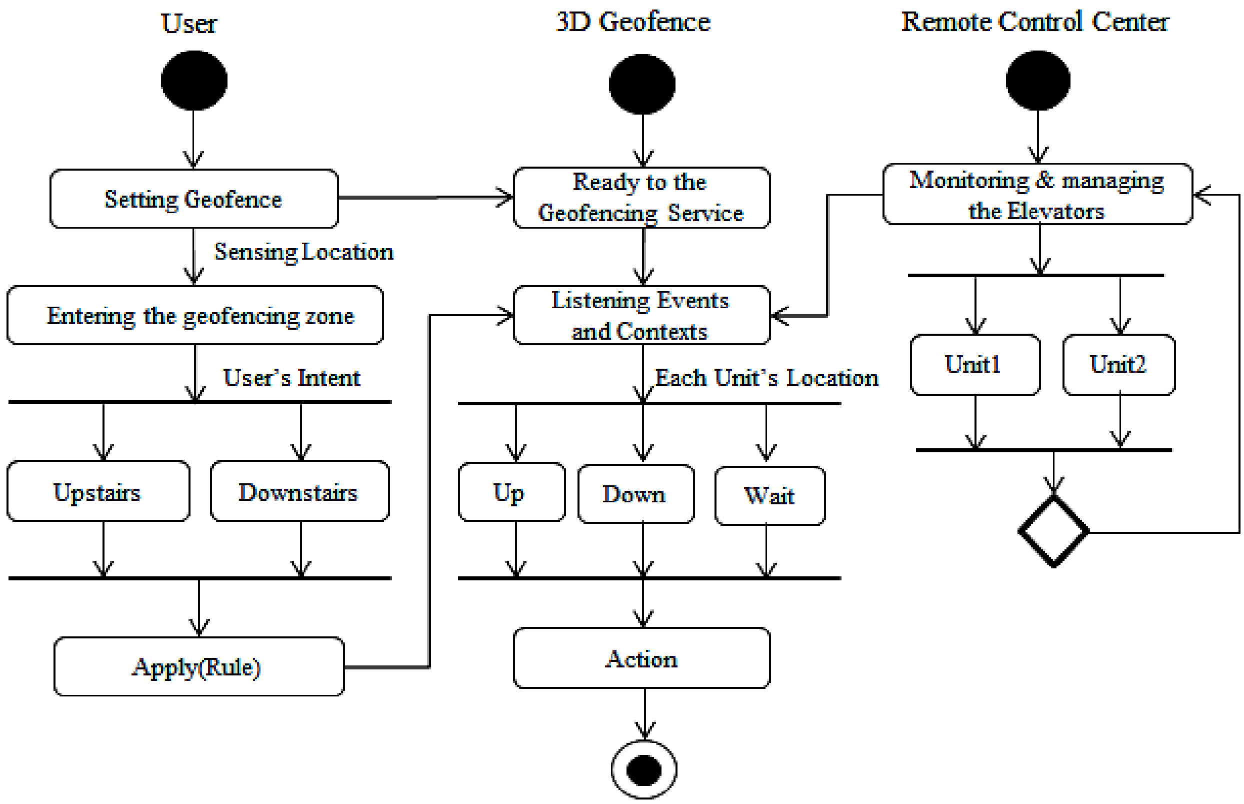

Figure. 3. An activity diagram

The rules as to when context awareness such as this should occur are shown in Table 1. The geofence should select one of elevators that is in the optimal floor in the context of several elevators, so that it dispatches the selected event to the correct control module.

In this situation, the user's contexts have at least three states, such as current location, up/down directions, and cancel. On the other hand, the contexts of each elevator too have four states, such as wait, move-up, move-down, and out of order. According to Bayes' rule, the probability of contexts per each elevator related to the user are organized by the following probability formula.

$$P(Y)= \sum_{x} P(Y|X)P(X) \quad (1)$$

where Y is the elevator's context information and X is the user's context information.

Even though we assume only two elevators, the model can be easily extended to multiple elevators, albeit with increased complication. However, the operating system and algorithm for multiple elevators is excluded here because it is beyond the scope of this paper. In order to simplify further, we reduce the context for one of the elevators. Table 1 shows the rule of context-awareness service for each elevator.

Table. 1. The rule for each elevator

Elevator's Direction/ Relative Location / **User's Current Location/Direction**		**Wait**			**Move-Up**			**Move-Down**		
		Equal	**Low**	**High**	**Equal**	**Low**	**High**	**Equal**	**Low**	**High**
Current Floor	**Upstairs**	default	proximity	proximity	pass	priority	less high	pass	less high	less high
	Downstairs	default	proximity	proximity	pass	less high	less high	pass	less high	priority

The left-side column of Table I indicates the user's location in the building and the direction in which he wishes to travel. The moving direction and relative location of the elevator in the above side row refer to higher than, lower than, or equal to that based on the user's current location.

For example, when a user is on the seventh floor and wants to go downstairs, one of the elevators that can be selected is a high priority, in that it is above the seventh floor and is moving downward. If there is no such elevator, the proposed 3D geofence platform will choose an elevator with a lower priority. Also, if one of the elevators is waiting at the same location as the user, it would choose to set this as the default. If one of the elevators is waiting at a different location from the user's current location, the 3D geofencing service selects the elevator that is closest to the user's position. By default, if the user is on the top/bottom floor, his intended direction of travel is automatically set to downward/upward, since this intent is obvious.

4. Experimental Results

We implemented the proposed 3D geofence platform with rule-based context-awareness service and computing for the IoT using smartphone based on the Android operating system[19]. To test the

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proposed platform, we created and applied a simulation that assumed the operation of multiple elevators. Because we could not use actual elevators in an experimental building, we built a server application that worked like the elevator.

The server application sets two elevators in Units 1 and 2, which operate independently of each other as the things of the IoT simulation model. The server application randomly generates a current floor number and the direction of movement of each elevator. Then, the system applies the proposed rule-based context awareness to compare with the user's current location and his intended direction of travel. The experimental results generated by the proposed platform were confirmed as follows.

Figure. 4 shows the initial screenshot in which the proposed 3D geofence is set up near the elevators inside the building. The pop-up window and the circle in Figure 4 show the information of the specified 3D geofence such as latitude/longitude, the radius of the barrier and its timestamp as the elapsed time of the geofence lifecycle. The information should be stored in the Geofence Local Repository and sent to the Geofence Management server, and then the specified 3D geofence is activated[8-14].

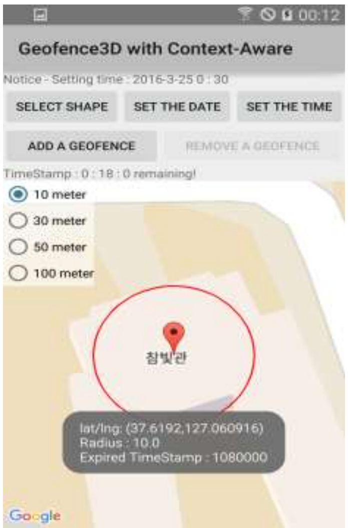

Figure. 4. An initial screenshot

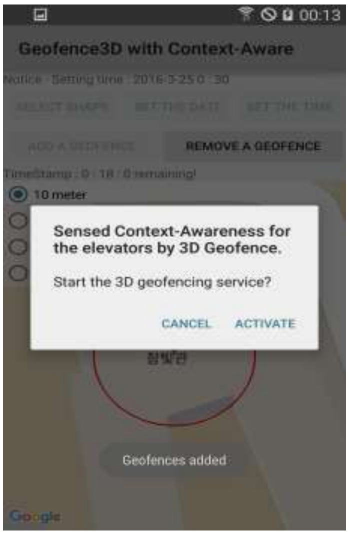

Figure. 5. A screenshot to activate the 3D geofencing service

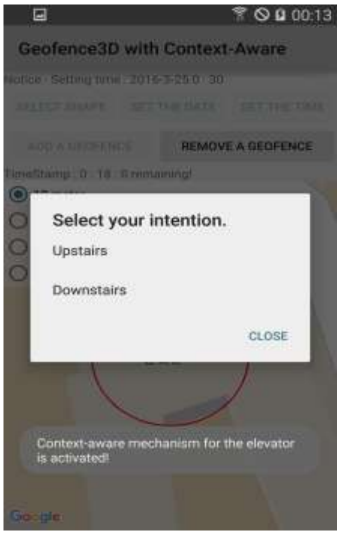

Figure. 6. A screenshot to query the user's intention

In Figure 5, as soon as the user approaches the specified geofence that had been set up in the building, the proposed 3D geofence platform notifies the rule-based context-aware mechanism for the elevator to allow the user to ride it, and begins the 3D geofencing service. Figure 6 shows a pop-up window query to ask the user his intended direction of travel.

If the user is on the 5th floor and wants to go downstairs, the proposed platform chooses Unit1 as one of two elevators, and dispatches the action to the elevator's control module to press the down-button, as shown in Figure 7. Here, the reason that the Unit 1 elevator was selected is because the proposed rule-based context awareness sensed that the user was on the 5th floor and that his intent was to go downstairs; the Unit 1 elevator was currently coming down from the 9th floor. On the other hand, the Unit 2 elevator may not be selected due to one of several inapposite reasons for the proposed rules, such as move-upward mode, non-proximity, or low priority.

Figure. 7. A screenshot to move downward from the 5th floor

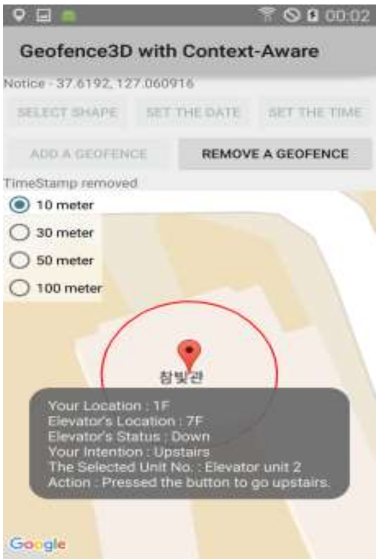

Figure. 8. A screenshot of the base floor

By default, if a user is on the bottom or top floor, it does not require selection to go upstairs or downstairs, since the user's intent is evident. Figure 8 shows that upon sensing that the user is on the 1st floor, the Unit 2 elevator, which is on the 7th floor, moves downward to the user's location. The reason that the Unit 2 elevator is selected too should be the proximity or the direction of travel, and so forth.

5. Conclusions

In this paper, we proposed an extended 3D geofence platform with rule-based context-awareness service to support the IoT, which can recognize and determine whether a user is in indoors or outdoors location.

The proposed platform consists of 3 components based on the 3D geofence framework, namely a context-awareness component, the things of the IoT, and a 3D geofence app. In order to implement rule-based context-awareness service and computing using the proposed platform, we consider the rule model based on a scenario for the IoT. The rule model adopts the elevator for reasons already mentioned as the things of the IoT. For all that, there are still lots of things(such as the elevator) that will be subjected to the IoT but which currently do not contain wired/wireless networks. The proposed platform can select the optimal one of multiple elevators according to user's intention, and shows the feasibility of rule-based context-awareness service for the IoT. As a result, we can save energy by the efficient operation of the elevators.

In future, we expect smart things for the IoT such as the smart-building, smart-car, smart-ship, smart-home, smart-farm. The proposed 3D geofence platform will be a valuable application for the IoT based on LBS.

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References

[1]. Gartner Press, "Gartner Says the Internet of Things Installed Base Will Grow to 26 Billion Units By 2020", 2013.

[2]. ABI Research, “More Than 30 Billion Devices Will Wirelessly Connect to the Internet of Everything in 2020”, 2013

[3]. Fickas S., Kortuem, G., Segall, Z., "Software organization for dynamic and adaptable wearable systems". International Symposium on Wearable Computers 1997; 56–63

[4]. Pew Research Center, "Main Report: An In-depth Look at Expert Responses", Internet, Science & Tech., 2014

[5]. PLATFORM, "Behind The Numbers: Growth in the Internet of Things", 2015

[6]. Wikipedia, https://en.wikipedia.org/

[7]. Charith Perera, Arkady Zaslavsky, Peter Christen, Dimitrios Georgakopoulos, "Context Aware Computing for The Internet of Things: A Survey", IEEE Communications Surveys Tutorials, 2013; 1-44.

[8]. Eom Young-Hyun, Choi Young-Keun, Sungkuk Cho and Byungkook Jeon,” FloGeo: A Floatable Three-Dimensional Geofence with Mobility for the Internet of Things”, JARDCS, 2017; 114-120.

[9]. Eom Young-Hyun, Choi Young-Keun, Hyunmi Yoo, Sungkuk Cho and Byungkook Jeon,” A Flexible Mobile-Geofence to support Connected-Cars Technology”, Korea Samrt Media Journal, 2017; 89-94.

[10]. Byungkook Jeon, Sungkuk Cho, “Design of 3D Geofence Model by Location-aware Mechanism,” INFORMATION, 2015; (18):3175-3180

[11]. Eom Young-Hyun, Choi Young-Keun, Sungkuk Cho and Byungkook Jeon,” Design and Implementation of a Framework of Three-Dimensional Geofence”, INFORMATION, 2016;.9(A): 3895-3900

[12]. Eom Young-Hyun, Choi Young-Keun, Sungkuk Cho and Byungkook Jeon, “A Time-Limited Three Dimensional Geofence using Timestamp”, IJAER, 2015;10(90):457- 460

[13]. Eom Young-Hyun, Choi Young-Keun, Sungkuk Cho and Byungkook Jeon, "A Mechanism to identify Indoor or Outdoor Location for Three Dimensional Geofence", The Journal of The Institute of Internet, Broadcasting and Communication(IIBC), 2016;(16):169-175

[14]. Eom Young-Hyun, Choi Young-Keun, Sungkuk Cho and Byungkook Jeon, "TemG : A Geofence Platform with Time-Limited Property", The Journal of The Institute of Internet, Broadcasting and Communication, 2016;(16):177-182

[15]. Byungkook Jeon, R. Young Chul Kim, "A System for detecting the Stray of Objects within User-defined Region using Location-Based Services", IJSEA, 2013;355-362

[16]. Ulrich Bareth, Axel Kupper, Peter Ruppel "geoXmart – A Marketplace for Geofence Based Mobile Services", 2010 IEEE 34th Annual Computer Software and Applications Conference, 2010; 101-106

[17]. Dmitry Namiot, "GeoFence services,", IJOIT, 2013;23-29

[18]. D. Namiot and M. Sneps-Sneppe, "Geofence and Network Proximity", Networking and Internet Architecture, 2013

[19]. Google Co., http://developer.android.com/

[20]. Carnot Institutes, "Smart networked objects and internet of things," Carnot Institutes' Information Communication Technologies and Micro Nano Technologies Alliance, White Paper, 2011

[21]. L. Atzori, A. Iera, and G. Morabito, "The internet of things: A survey," Comput. Netw., 2010; Vl(54):2787–2805

[22]. G. Kortuem, F. Kawsar, D. Fitton, and V. Sundramoorthy, "Smart objects as building blocks for the internet of things," IEEE Internet Computing, 2010;(14):44 –51

[23]. C. Morbidoni, "Rapid prototyping of semantic mash-ups through semantic web pipes," Proc. of the 18th Int'l. conf. on World Wide Web,2009;581–590

[24]. A. Dohr, R. Modre-Opsrian, M. Drobics, D. Hayn, and G. Schreier, "The internet of things for ambient assisted living", Seventh International Conf. ITNG, 2010;804–809

[25]. Mashable, http://mashable.com/2011/12/16/geofencing-texts-shoppers

[26]. Google Playstore, https://play.google.com/store

[27]. Apple Appstore, http://www.apple.com/kr/itunes/

[28]. ThyssenKrupp Co., MAXIMIZING CITY EFFCIENCY, TK-Elevator-MAX-Report.

[29]. J. Bailey, A. Poulovassilis, P. T. Wood, "An event-condition-action language for XML," Proc. of the 11th Int'l. Conf. on World Wide Web, 2002;486-495